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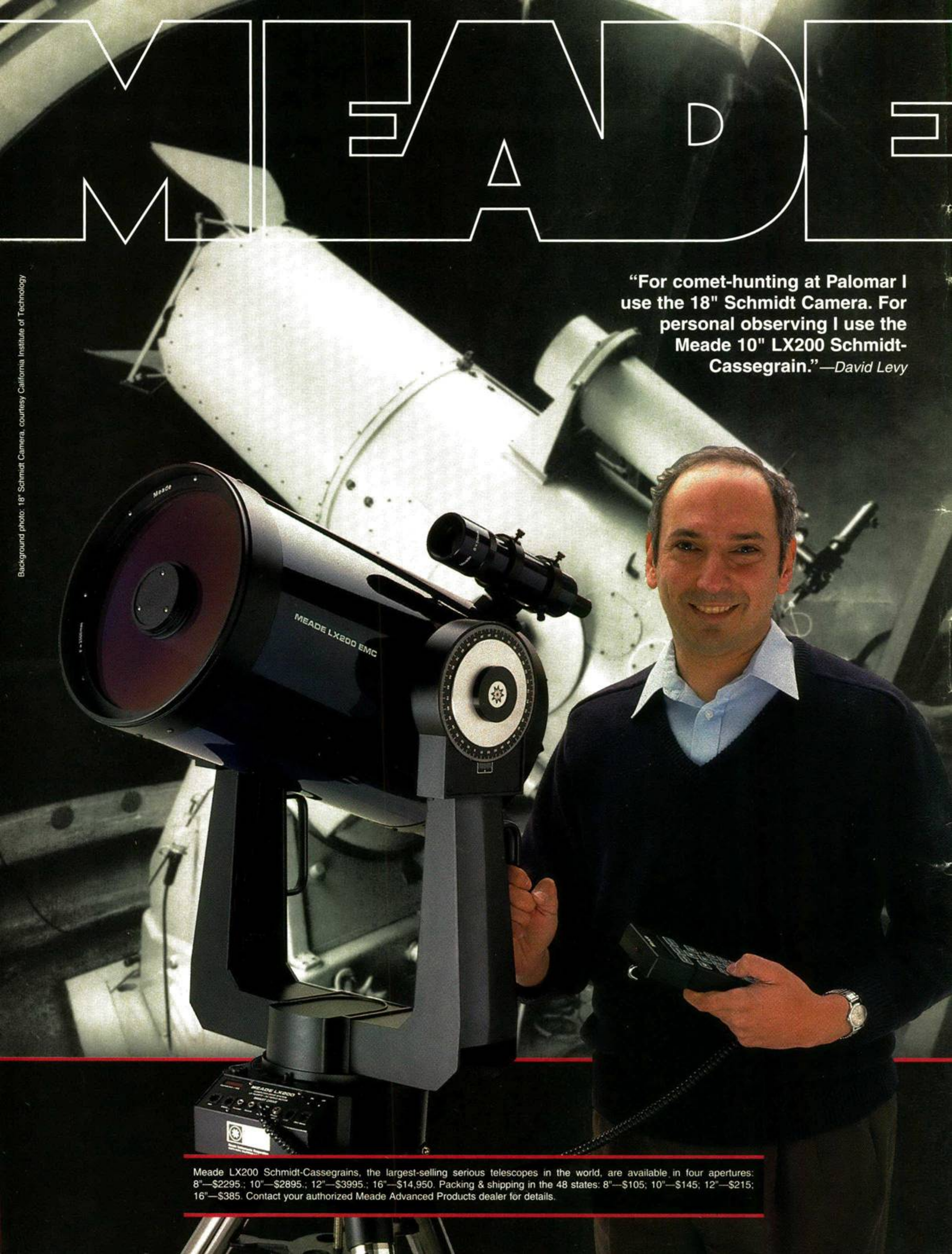

Background photo: 18" Schmidt Camera, courtesy California Institute of Technology

"For comet-hunting at Palomar I use the 18" Schmidt Camera. For personal observing I use the Meade 10" LX200 Schmidt-Cassegrain."—*David Levy*

Meade LX200 Schmidt-Cassegrains, the largest-selling serious telescopes in the world, are available in four apertures: 8"—$2295.; 10"—$2895.; 12"—$3995.; 16"—$14,950. Packing & shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 16"—$385. Contact your authorized Meade Advanced Products dealer for details.

A few words from a special Meade customer…

"With all of the attention that Comet Shoemaker-Levy 9 has been receiving lately because of the upcoming comet crash into Jupiter, I thought you might like to know the role that your company has played, not only in my development as an amateur astronomer, but also in many of the discoveries I've been fortunate enough to make.

My first Meade telescope, purchased in 1978, was your 4" f/15 refractor, an excellent instrument that gave me the finest images of Jupiter I had ever seen. As the years progressed, I have used the Meade 16" Starfinder Newtonian and 8" LX200. My current instrument is your 10" LX200. All of these telescopes show quality engineering, and all have performed extremely well in my observing programs. For all of its technical features, the 10" LX200 is probably the easiest telescope to use that I've ever observed with. I do not hesitate to recommend it.

I also use the LX200 to open up the skies for children; these programs are even more important to me than comet hunting. High-resolution telescopes like this can show the next generation that there is more to life than television.

Over the years I've acquired quite a collection of Meade accessories, especially eyepieces. You might be interested to know that all 7 of my visual comet discoveries were made using Meade eyepieces. Your Series 4000 eyepieces are superb, with the Super Wide 32mm (an incredible eyepiece) being a particular favorite of mine.

Beyond my own experience with Meade products, I continually hear good things from friends and colleagues about Meade Instruments as a company—that you're always "there" to back-up your product with after-sale service, advice, and support.

So to all of you at Meade Instruments, many thanks for your contributions to amateur astronomy and to this amateur astronomer in particular. If you'd like to reprint this letter, you have my permission. Everything I've said comes from the heart.

With all best wishes, David H. Levy

See David at these events on *The Great Comet Crash Tour:*

April 25, 7:30PM: Flandrau Science Center and Planetarium, University of Arizona, Tucson AZ; 602-621-4515.

April 29, 8:00PM: Miami Space Transit Planetarium, Miami, FL; 305-854-2222.

May 4 (observing), **May 5** (lecture): Kansas City Museum Planetarium, Kansas City, MO; 816-483-8300.

May 16, 7:30PM: Griffith Observatory and Planetarium, Los Angeles, CA; 213-664-1191.

May 21, 8:00PM (lecture); **May 22, 1:00PM** (daytime star party): Cranbrook Institute of Science, Bloomfield Hills, MI; 313-654-3200

May 23, 7:30PM: American Museum-Hayden Planetarium, New York, NY; 212-769-5900.

May 24, 8:00PM: Fairfield County Astronomical Society, Stamford, CT; 203-721-9529.

May 25, 8:00PM: Astronomical Society of Greater Hartford, Hartford, CT; 203-721-9529.

June 11, 7:30PM: Newcombe Theatre, Royal B.C. Museum, Victoria, British Colombia, Canada; 604-387-5745.

June 12, 1:00PM: Dominion Astrophysical Observatory N.R.C., Royal B.C. Museum, Victoria, B.C., Canada (children only); 604-387-5745.

June 13, 8:00PM: Star Theatre, H.R. MacMillan Planetarium; Vancouver, B.C., Canada; 604-736-4431.

June 14, 8:00PM: Lecture Hall, H.R. MacMillan Planetarium; Vancouver, B.C., Canada; 604-736-4431.

June 23, 7:15PM: Koch Science Centre and Planetarium, Evansville, IN; 812-425-2406.

June 24, 8:00PM: Cleveland Museum of Natural History, Cleveland, OH; 216-231-4600.

July 10: Fels Planetarium, Franklin Institute Science Museum, Philadelphia, PA; 215-448-1208.

July 21: "Jupiter Watch Party" with The Planetary Society, U.S. Naval Observatory, Washington, DC; 818-793-5100, for pass information.

July 22: "Jupiter Watch Presentation" with The Planetary Society, Carl Sagan, Carolyn & Eugene Shoemaker; Stouffer Mayflower Hotel, Washington DC; for tickets: 818-793-5100.

August 5 - 6: *STARFEST* star party, Mount Forest, Ontario, Canada; 416-761-1798.

August 27: Lecture and observing at The Pacific Observatory, Blackcomb Mountain, Whistler, B.C. Canada; 604-932-3141.

For information on additional appearances and book-signings David Levy will be making, call **1-800-227-1114.**

Comet Shoemaker-Levy 9 **is composed of at least 20 separate fragments, all of which will impact Jupiter's surface between July 16 - 22, 1994.**

photo by James V. Scotti, *Spacewatch*

One of the world's most renowned amateur astronomers, David Levy began his astronomical career at age 12 and has since discovered or co-discovered 19 comets, including Shoemaker-Levy 9, scheduled to crash into Jupiter in July. He has authored over 200 articles for major scientific magazines; his books include *The Quest for Comets* and *Skywatching,* both just published; and *An Observing Guide for Comets, Asteroids, Meteors, and Zodiacal Light* (with S. J. Edberg). David has served as an observer with the Planetary Science Institute; currently he is a senior instructional specialist at the University of Arizona's *Project ARTIST* and an observer with the Palomar Asteroid and Comet Survey.

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July 1994 Vol. 22, No. 7

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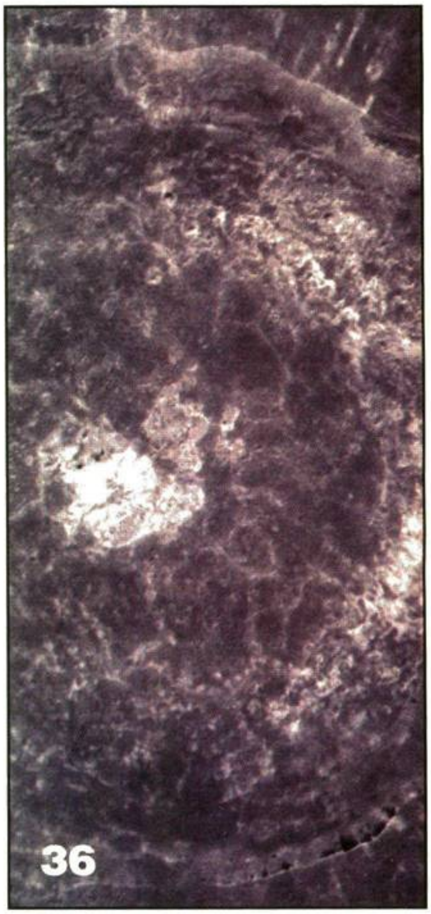
Apollo didn't just land 12 men on the Moon. It gave geologists their first hands-on look at an alien world. By Graham Ryder.



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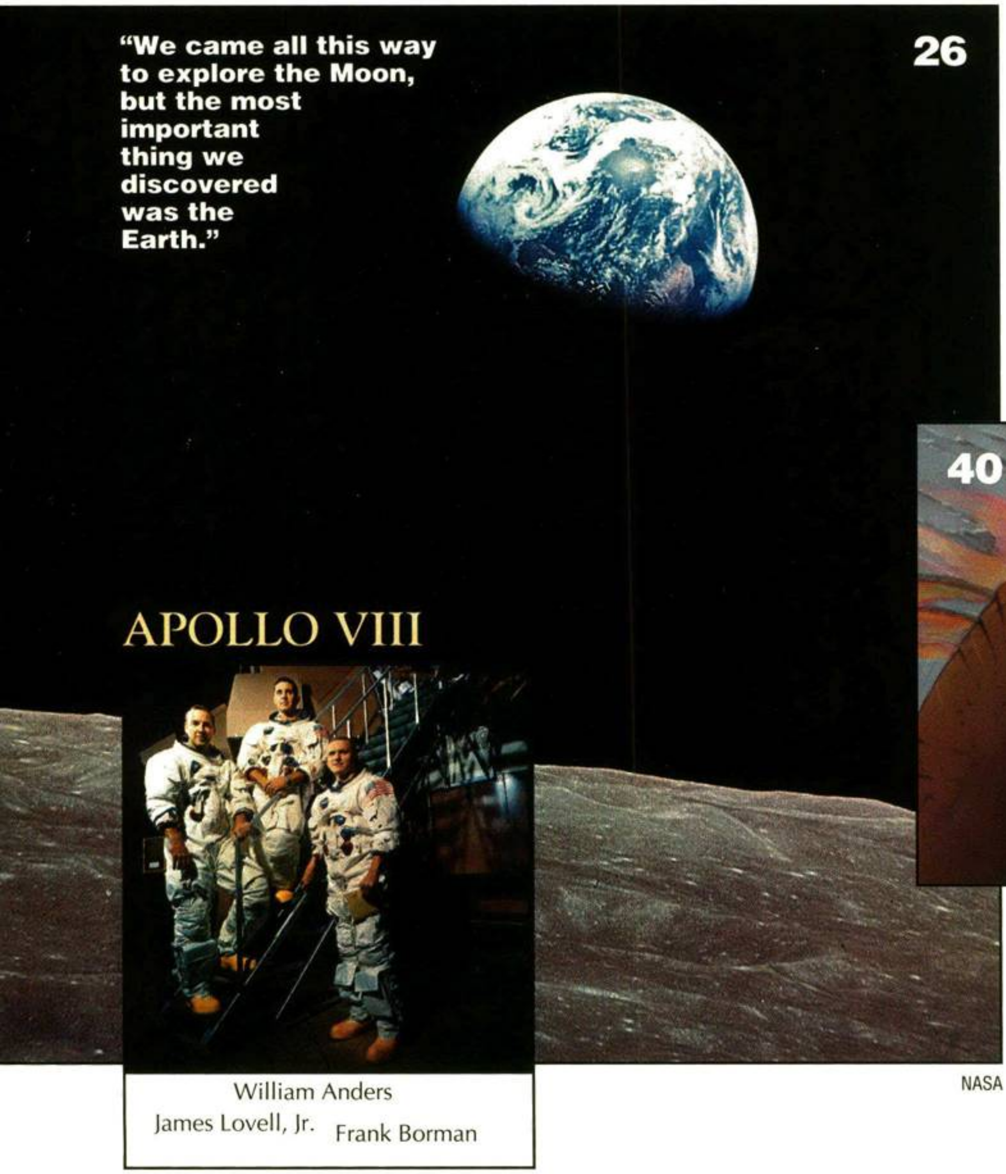
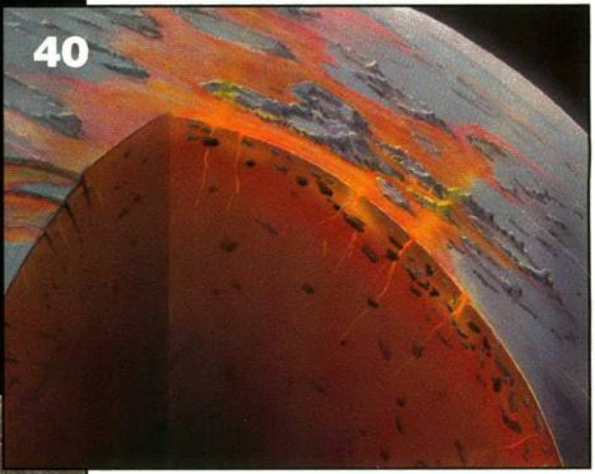


"We came all this way to explore the Moon, but the most important thing we discovered was the Earth."

William Anders
James Lovell, Jr. Frank Borman

NASA



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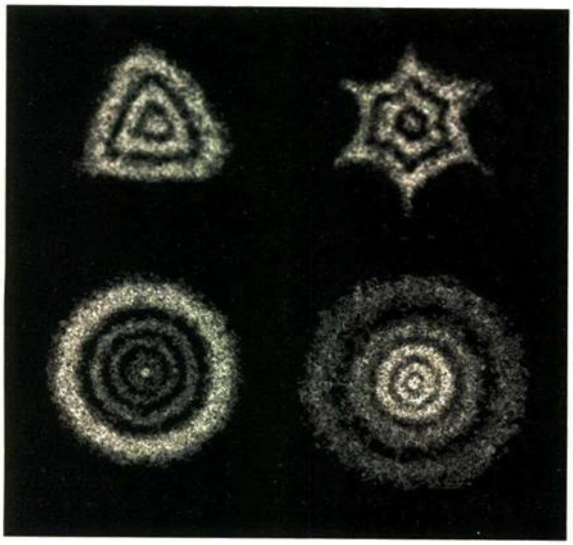

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COVER

THE LAST MAN to walk on the Moon, Gene Cernan salutes Old Glory in the desolate Taurus-Littrow Valley. This month ASTRONOMY celebrates the grand adventure of Apollo on this, the 25th anniversary of Neil Armstrong's first steps on the lunar surface (page 26). NASA photo.

BEHIND THE SCENES

The Day We Went to the Moon

The late afternoon held the day's warmth, as July afternoons often do in Boston. We sat on the floor in the attic apartment of a friend, the four of us gathered around a portable TV. The windows were open to catch a breeze, but all they brought was the sound of cars passing on the street below.

"Down 2½ . . . Picking up some dust," Aldrin's voice crackled.

"30 seconds." That was Capcom in Houston reading out the remaining fuel. Our tenseness edged up a notch.

"Forward . . . Drifting right. . . ."

A staticky silence followed, broken by . . .

"Contact light."

At that moment I knew they'd made it. I released my breath as the unseen LM dropped the last couple feet to the lunar surface. A few words of astro-speak followed as the crew shut down the LM's engine. Then Armstrong said,

"Houston, Tranquillity Base here. The Eagle has landed."

Despite the quarter century since that incredible day, its events remain fresh and bright in my memory — and unless you weren't yet born or were too young, it's probably just as fresh in yours, also. Later missions saw and did more and ranged farther afield, but the flight of Neil Armstrong, Edwin Aldrin, and Michael Collins to the lunar Sea of Tranquillity stands as a towering monument.

To commemorate that first Moon landing, this month's ASTRONOMY looks at the Moon and the Apollo program with three feature articles. The first, by Andrew Chaikin, takes you into the minds and memories of the men who flew there. After reading it, I think you'll agree that despite being chosen for their stoical "right stuff," no one who went to the Moon came back unaffected by the experience. Then lunar scientist Graham Ryder unfolds the history of the Moon — a story that couldn't have been written without Apollo. Ryder's research involves taking apart Moon rocks and soil to study how their components came to be. As he says, "For me, the Apollo program is still going on." Last, we present a portfolio of lunar images from the Clementine spacecraft, now on its way to the near-Earth asteroid Geographos, which it will fly past late in August.

If you had asked me on that long-ago July day where we'd be in 25 years, I could never have guessed. Yes, NASA completed its lunar reconnaissance — but I figured we'd have a Moon base by now. On the other hand, who expected the wonders shown by Voyager, or the geological richness of Venus as seen by Magellan? As I write this, NASA's future is clouded and uncertain, although its problems are more political than technical. What will Apollo 11's 50th anniversary bring? That's up to all of us to help determine — and it's not too soon to start.

Sincerely,

Robert Burnham
Editor

LETTERS

Hubble's New Vision

I enjoyed seeing the amazing photos in "Hubble Better Than New" (April 1994). I was particularly impressed by the image of the massive star Eta Carinae and its surrounding nebula. The similarity between this object and the planetary nebula NGC 2346, pictured on page 42, is striking. The similarity poses a question: Is the Eta Carinae Nebula in the early stages of becoming a planetary nebula? — *Robert A. Murrell, Berkeley, Michigan*

— Eta Carinae is too massive a star to produce a planetary nebula. But Eta Carinae, like a giant star creating a planetary nebula, is losing mass. And the wind from Eta Carinae's surface shapes the gas and dust just as a giant star's wind shapes a planetary nebula. See "Hypergiants" (March 1994) for more on Eta Carinae.

Circle the Wagons!

The ancient craters of small Martian volcanos ("Exploring Small Volcanos on Mars," April 1994) greatly interest not only planetary scientists but also those who wish to plan human colonies on the Red Planet. These gentle, worn-down rings, together with the impact craters, will surely be the sites of the first human settlements on other solar system bodies. Like the wall-ringed cities and forts of the Old World, they will provide sheltered, low-cost habitats for the earliest settlers in the solar system. Covered rim-to-rim by transparent material, sealed and pressurized, and connected by tunnels, they will become oases in the desert. I can hardly wait! — *Alex Farkas, Sunnyvale, California*

Light Fight

I read with fascination the letter from Hans Gunter Gnodtke (April 1994) in which he reported the German Bundestag committee's rejection of light

(continued on page 14)

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10. Ultra-reliable electronic systems —*Thousands* of Meade LX200's have been sold worldwide. State-of-the-art designs and production systems, combined with exhaustive laboratory and field testing, make these **the most trouble-free serious telescopes ever manufactured.**

11. Meade *Version 3.20* software— The very latest in telescope operating systems. Permits quick ***(less than 10 seconds!)*** 2-star alignment of the LX200 in altazimuth mode, without requiring latitude or longitude input, without even leveling the tripod. Just use 2 easy-to-find reference stars and the telescope tracks and actuates GO TO with extreme precision.

FREE!

Through August 31, 1994, receive the Meade 64,350-object library *at no charge* when you order any 8", 10", or 12" LX200!

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12,921	galaxies from the Uppsala General Catalog; the complete UGC catalog.
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5,386	IC (Index Catalog) objects; the complete listing of IC objects.
21,815	variable stars; the complete listing from the General Catalog of Variable Stars.
15,928	stars from the Smithsonian Astrophysical Observatory (SAO) catalog of stars brighter than 7th magnitude.
351	alignment stars for the LX200 telescope.
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8	major planets from Mercury to Pluto.
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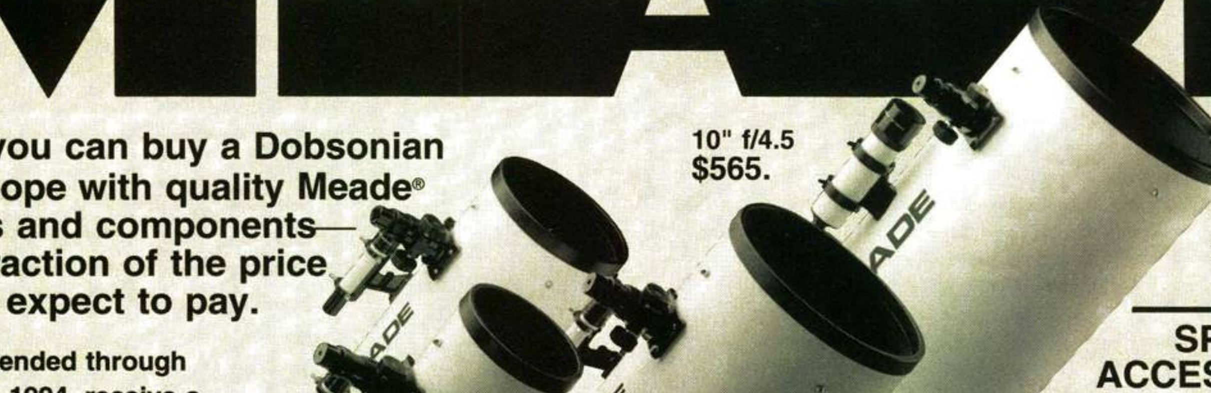

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Shown with optional #637 6 x 30mm or #545 8 x 50mm Viewfinders.

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Starfinder Dobsonian 16

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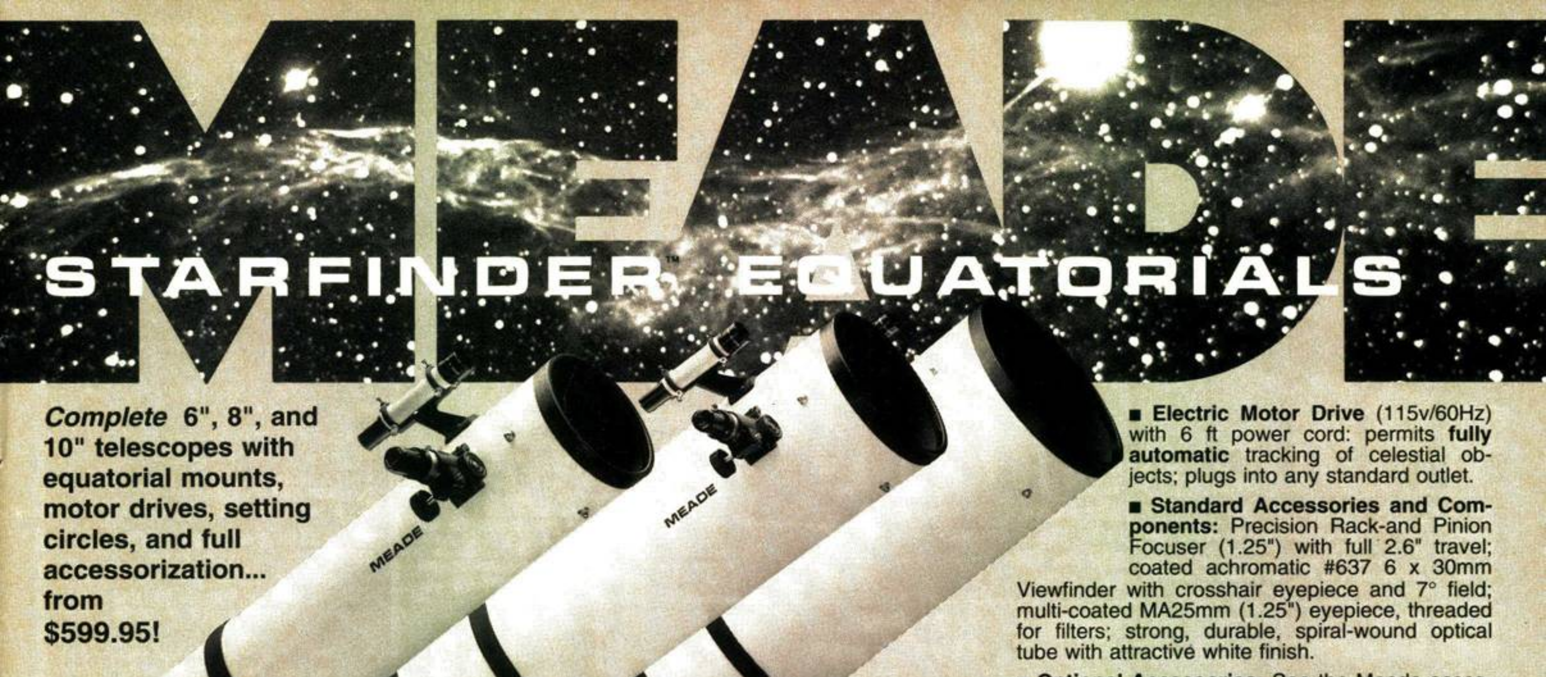

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Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types for 1994, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm each: **$87.95** (3.29)

32mm (52°); **40mm** (44°); each: **109.95** (3.79)

56mm (52°; 2") **229.95** (4.78)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (3.60)

Series 4000™ Super Wide Angle

For exquisite wide-angle images at low-to-medium powers, ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8, 18, and 24.5mm are superb complements to the #140 Barlow.

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Series 4000™ Ultra Wide Angle

The ultimate eyepieces; extreme image sharpness over an amazing 84° field.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)—**4.7mm: $179.95** (3.29); **6.7mm: 219.95** (3.29); **8.8mm** (1.25"/2"): **269.95** (4.78); **14mm** (1.25"/2"): **329.95** (4.78)

Series 4000™ #140 2x Apochromatic Barlow Lens

The most advanced Barlow Lens available for commercial telescopes; includes 3-element, air-spaced optics, multi-coated. Unmatched in image resolution, contrast, and color correction. Accepts1.25" eyepieces. Lens dia. 28mm; clear aperture 26mm.

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This offer is valid between February 20 and June 30, 1994 at participating Meade dealers and is subject to eyepiece availability.

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The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce excellent results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$59.95** (3.29) **Any 2: $52.95** each; **Any 3: $48.95** each; **Any 4 or 5: $46.95** each.

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A perfect complement to the Series 3000 Plössls at left, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25", threaded for filters. Apparent field: 44°. **$79.95** (3.79)

Series 4000 Photo-Visual Color Filters (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

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Moon Filter #ND96—Reduces brightness by 87%.	**15.95** 2.29)
Set #1—4 filters: #12, #23A, #58, #80A	**49.95** (2.79)
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#911B
#910B
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#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high contrast observing of faint nebulae.

#908B—Threads into 1.25" eyepieces; 26mm dia.	**79.95** (2.98)
#910B—Threads into 2" eyepieces; 44mm dia.	**119.95** (3.29)
#911B—Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.29)
#908N—Threads into 1.25" eyepieces; 26mm dia.	**89.95** (2.98)
#910N—Threads into 2" eyepieces; 44mm dia.	**129.95** (3.29)
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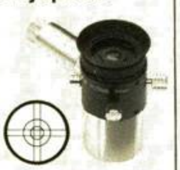
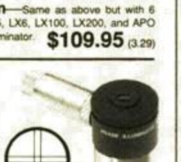


Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25" **$129.95** (3.29)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$109.95** (3.29)

MA 12mm Illuminated Reticle Eyepiece



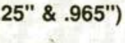
Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control. **$99.95** (3.29)

MA 12mm-Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.29)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$99.95** (3.29)

Camera Adapters (1.25" & .965")



Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.

.965": $27.95 (2.79) **1.25": $29.95** (2.79)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.79)

Tele-Extenders

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$29.95** (2.79)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece. **$39.95** (2.79)

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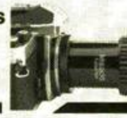

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera. **$26.95** (2.79)

2X Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (3.29)

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#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25" **$59.95** (3.29)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (2.79)

Modified Achromatic Eyepieces

An improvement on the traditional Kellner design, these 3-element Modified Achromatic eyepieces give sharp, faithful, well-corrected images of the Moon, planets, and deep-space at an economical price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$29.95** (2.79)

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pollution control in Germany because "stray light is the inevitable consequence of our civilization . . . and therefore has to be accepted."

Perhaps members of the Bundestag will visit Arizona where nearly every city and town has passed an ordinance governing light fixtures and keeping their energy on the ground, where it's needed, and not in the sky. Civilization is not the issue here — ignorance is. — *John Gardner, Charleston, Illinois*

San Diego Messier Marathon

Thanks for publishing Phil Harrington's article "Running a Celestial Marathon" (March 1994), for it motivated members of the San Diego Astronomy Association to finally attempt a Messier Marathon.

On Saturday, March 12, 1994, we met at our club's observing site east of San Diego. After a few of us found the 20-hour-old Moon, we settled into deep-sky observing. We unlimbered our scopes and spotted many galaxies. An hour into the marathon, we saw the space shuttle pass overhead.

Although most of the morning observing was hampered by strong gusts of wind, six of us remained at dawn. — *Henry Walker, San Diego, California*

Experimental Spacecraft Society

The Experimental Spacecraft Society wishes to build and launch a small (10-inch to 16-inch) telescope into low-Earth orbit for use by amateurs. The group's plans are still being discussed and amateur astronomers may contribute ideas and participate in the process. Readers of ASTRONOMY are encouraged to contact us for more information. — *Linda Kenny-Sloan, director, Experimental Spacecraft Society, 17701 South Avalon Blvd., #407, Carson, CA 90746, e-mail: l.k.sloan@genie.geis.com*

Don't They All Have Names?

In your Reader Reports for April 1994, David E. Thomas shared a very nice lunar image of an unnamed lunar crater and the Straight Wall (page 90). I was momentarily startled at the term *unnamed lunar crater.* Possibly this refers to the region surrounding the Straight Wall and bounded by the highlands that arch northwest from the crater Thebit, slightly right-of-center in the photo.

Indeed, no specific name for this area appears in the literature. Its resemblance to other, traditional "craters" may be an artifact of the Sun angle when the image was made. — *Craig D. Wandke, Santa Cruz Astronomy Club, Monterey, California*

— Although a prominent landmark (the Straight Wall, or Rupes Recta) passes through the middle of the 200-km-wide feature, it has never been officially named, probably because of its greatly dilapidated state. Among the classic lunar observer's guides, only The Moon *by H. Percy Wilkins and Patrick Moore (1955) mentions it, saying that the Straight Wall "lies inside and nearly in the centre of a large old ring, now barely traceable." Michael Kitt's* The Moon *(1992) mentions it as a ghost crater. The unnamed feature is, however, designated as crater 31318 in the catalog of lunar craters prepared at the University of Arizona in the mid-1960s, and it is plotted on that work's outline chart.*

Taking It to the Streets

On a recent Wednesday night I took my 8-inch Dobsonian to a church function for kindergarten through eighth-grade kids and set up the scope in the parking lot. Many of the kids had the opportunity to peek through the scope.

My favorite astronomical object is Saturn, so I naturally had a desire to

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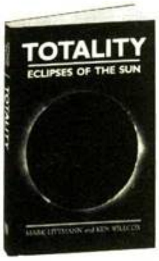
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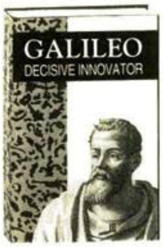
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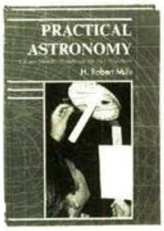
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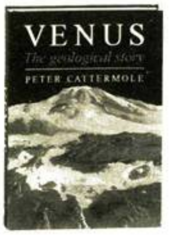
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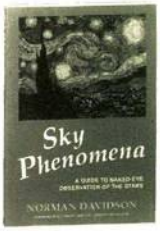
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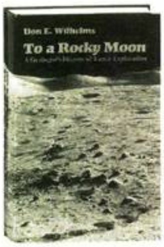
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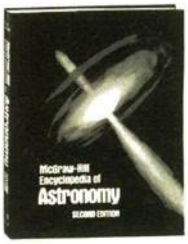
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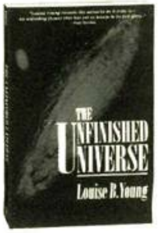
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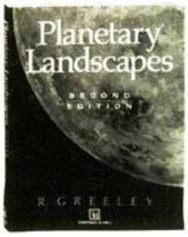
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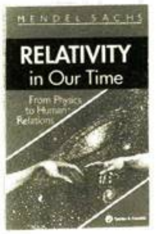
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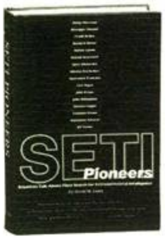
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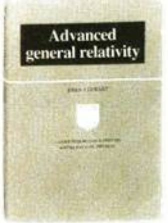
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share a view of it with the kids. As the kids started filing out of the classrooms I began to get questions like, "What is that thing?" and "That doesn't look like a telescope — is it one?" and so on.

I invited some of the kids to look through the scope at Saturn and its rings. In a matter of minutes I had a line of 30 or 40 kids (and adults) wanting a look at the Ringed Planet. The comment I heard most was "Oh, wow!" I think that taking astronomy to the people who can enjoy it but don't know about it is the best way to create interest in the hobby.

I also want to thank the editors of ASTRONOMY for "Building Astronomy's Future" (September 1993). I've shown the article to several other teachers who agree that a hands-on approach works best, so they would like me to set up my scope for their classes. — *Roger C. LeSuer, Fallon, Nevada*

Got Those Summer Observing Blues

For some years I've been amused by reading comments in ASTRONOMY from observers who stay inside during the winter. It's cold, they claim. I live in northern Scotland, which must be as cold as or colder than much of the northern United States and can't wait for wintertime observing. Why waste three or four months because of the cold? Bundle up and get out there!

In northern Scotland we must appreciate the winter skies because it never gets dark here in the summer. I give up winter observing only when the secondary mirror is iced over. — *W. D. Eaves, Thurso, Caithness County, Scotland*

Telescope Time Payment Plan Exists

In response to Roger Lilly's letter (March 1994) asking for a telescope manufacturer's time payment plan, I suggest that most telescope retailers do have such a plan. It's called Mastercard, Visa, Discover, or Optima. Also, most telescope buyers have access to yet another time payment plan of their own. It's called a personal loan from their bank or credit union.

The sad fact is that most telescope retailers in today's astronomy market can't afford to act as a bank for their customers. The thin profit margins most mail order dealers work at simply won't allow them to pay for their inventory, pay their rent, pay their daily operating expenses, pay their employees, put their kids' food on the table, pay their taxes, *and* make long-term loans to their customers.

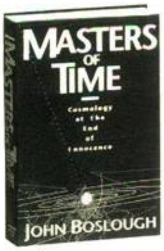
Let the credit unions and banks — whose business it is to loan money — do what they do best. Let *them* finance the telescope purchase. Let the telescope dealer concentrate on what he does best — making sure the customer has the right telescope. That way, everyone wins — the bank, the telescope retailer, and the telescope buyer. — *Fred C. Bieler, Astronomics/Christophers, Ltd., Norman, Oklahoma*

Corrections

In "Exploring Small Volcanos on Mars," (April 1994), the fifth paragraph contains an editorial error. The third sentence should read "While all explosive eruptions put out lava that has a medium to high silica content, . . . "

In the New Product Announcements for March 1994, the roof prism binoculars from Europtik are the "From JENA" brand. Our apologies for the editorial oversight. ☐

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187, or on Internet, use 72000.2704@CompuServe.com. Letters may be edited for length and clarity.



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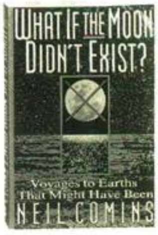

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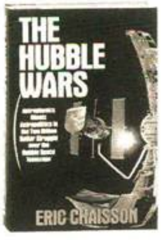

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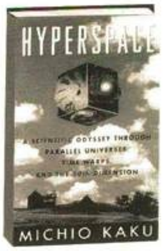

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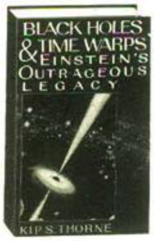

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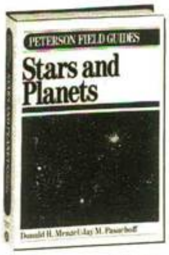

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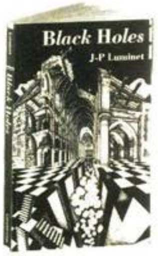

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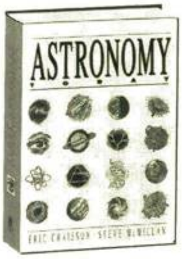

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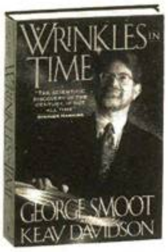

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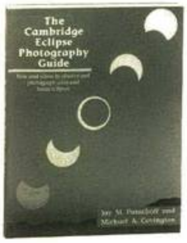

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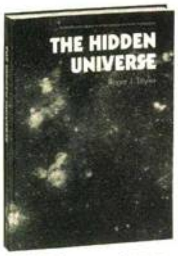

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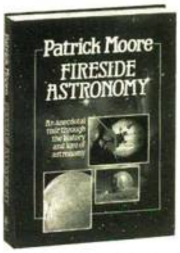

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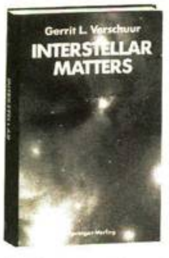

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Appreciating Apollo

by Ian Broadbent

I suspect that for many people the Apollo Moon flights marked only a brief pause in the monotony of life — hours of television coverage that seemingly amounted to nothing. These viewers probably protested when newscasters interrupted *I Love Lucy* to provide an update on the astronauts' extravehicular trips. But for a few of us, the events of those uniquely inspiring days bit deep.

Vivid memories flash through my mind: scale models depicting landing sites and the cheers of the people in the TV studio when Apollo 11 touched down in the Sea of Tranquillity. And for later flights, announcers described each scene as astronauts drove their rovers to a stop that disclosed some new mood of the alien landscape: panoramic views revealing smooth, bright rocks strewn across an ancient terrain and close-up scenes such as the one at Split Rock during Apollo 17.

But regrettably when I started secondary school, I lost interest in space, which I blame on the pressures of schoolwork. Five years later, my passion for space reawakened when I stumbled across an atlas that showed constellations and the surface of the Moon. I began a desperate search for Orion without knowing its size or whether it was even visible in the sky at that time of year. My father came to the rescue, drawing on his Royal Air Force navigational skills, and pointed out Orion rising in the sky on a crisp November night.

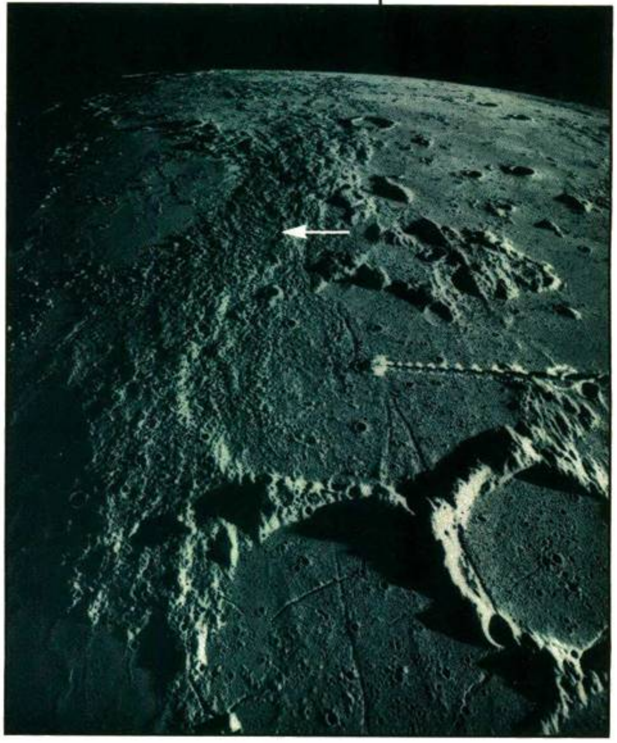
From then on my interest snowballed as I identified other constellations and viewed the planets. I remember seeing Jupiter and Mars lying close together in Leo during their 1980 conjunction. Apollo, though, lurked in the recesses of my mind.

My first images of the lunar surface came through a homemade 30mm telescope that shook at every touch. The scope delivered a shimmering image that kept the few craters I could see just out of the reach of clarity. But the view was stimulating enough to make me build a 6-inch reflector. After six months of hard work, it was finished and I could hardly wait to test it on the Moon.

It's almost impossible to describe my feelings when I saw the Moon's surface clearly for the first time. I was viewing another world. Apollo came booming back at me like an express train thundering out of a tunnel. I felt a new respect for and understanding of the 24 men who ventured to the Moon. (Nine teams of three astronauts went to the Moon but three astronauts went twice.)

From that first tantalizing view of the Moon with the 6-inch scope, I slowly developed skills in tracking down lunar features. Fleeting glimpses of subtle detail during moments of rock-steady seeing allowed me to build a slow but sure picture

Apollo 14 landing site (arrow) as seen from orbit

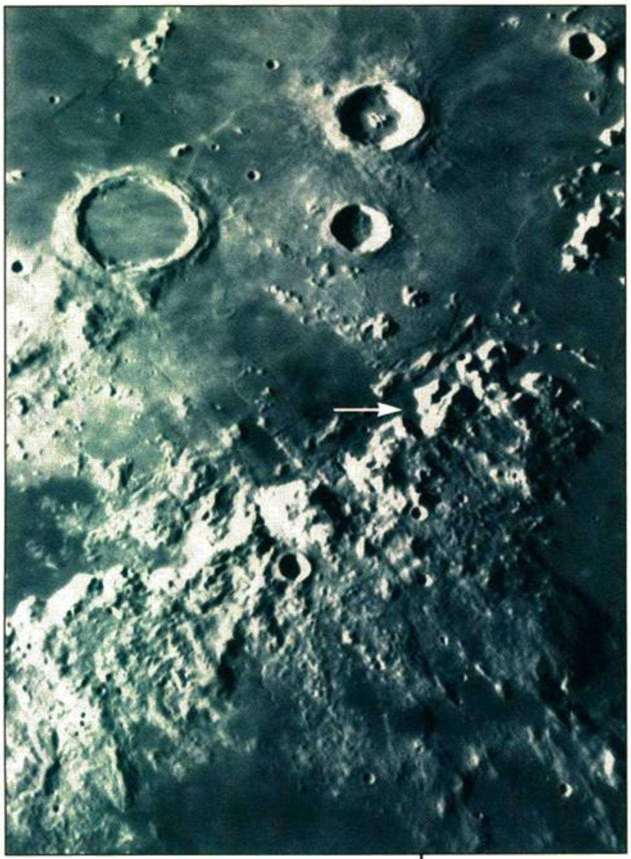


Apollo 16, NASA

of the lunar terrain. Oh, to have seen these features from lunar orbit!

While the Apollo 8 astronauts found the Moon hostile and forbidding, Apollo 10's crew reveled in its strangeness. To Mike Collins of the Apollo 11 crew, it was "not a very welcome place." Said Apollo 15 astronaut Dave Scott, "It is absolutely mind-boggling up here — unreal."

The "Apollo time" I spent glued to a TV set has blended with my telescopic viewing time. The result is an enhanced personal meaning. I think of venturing down among these ancient mountains and craters, practically intact from the time billions of years ago when the bombardment that produced them took place.


Christian Arsidi

Apollo 15 landing site (arrow)

While sketching the Moon's surface, I often feel an urge to view one of the landing sites. Without a doubt, the sites for Apollo 15 and 17 prove the easiest to find.

The Apollo 15 site, near the crater Archimedes, has the Apennine mountains looming massively on the eastern side and Palus Putredinus (the Marsh of Decay) to the west. Hadley Rille just to the west of the landing site pops into view during good seeing. Hadley Delta is a mountain to the south that shows St. George crater on its side during good seeing. At 600x with my 12-inch scope, texture and detail begin to reveal themselves in Hadley Delta, the rille, and Mons Hadley to the north. Fine undulations along the rille's length appear most clearly when the rille fills halfway with shadow. Such times bring to mind Dave Scott and Jim Irwin's descent into the rille on their third and final exploration of the surface. For them, the opposite wall of the rille could seemingly be reached in a few short steps, though it actually lay almost a mile away.

Apollo 17 landed in the Taurus-Littrow Valley that borders the eastern shore of Mare Serenitatis. The site lies between the crater Littrow and Mons Argaeus. Distinct landmarks exist here but on a smaller scale than for Apollo 15's site. The valley is somewhat elusive, although fascinating to study at high power under good conditions.

Two of the other sites — those for Apollo 14 and 16 — are somewhat easy to find. Apollo 14 landed north of Fra Mauro, a ringed plain that sits at the boundary between Mare Insularum and Mare Cognitum. Fra Mauro itself is a superb feature when viewed at waxing gibbous phase or at waning crescent. The Descartes highland site of Apollo 16 is also topographically rich, making it difficult to identify the landing site in the jumble of damaged craters. Look about one crater diameter due north of Descartes to find the site.

The remaining two sites are hard to find. The site for Apollo 11 lies about three crater diameters west of Sabine and Ritter on the west edge of Mare Tranquillitatis. Apollo 12 came down in Mare Insularum, about two crater diameters southeast of the crater Lansberg.

Anyone with a small scope can explore the Moon in intimate detail. Such an effort ties you directly to all the earliest lunar observers who struggled to see the same rilles and mountains out of the boiling blur. So it's easy to pretend you're the first person ever to see the Moon. Still, I envy the first observer who saw Triesnecker Rille through a scope and even more the 24 astronauts who saw it firsthand as they orbited the Moon. ☐

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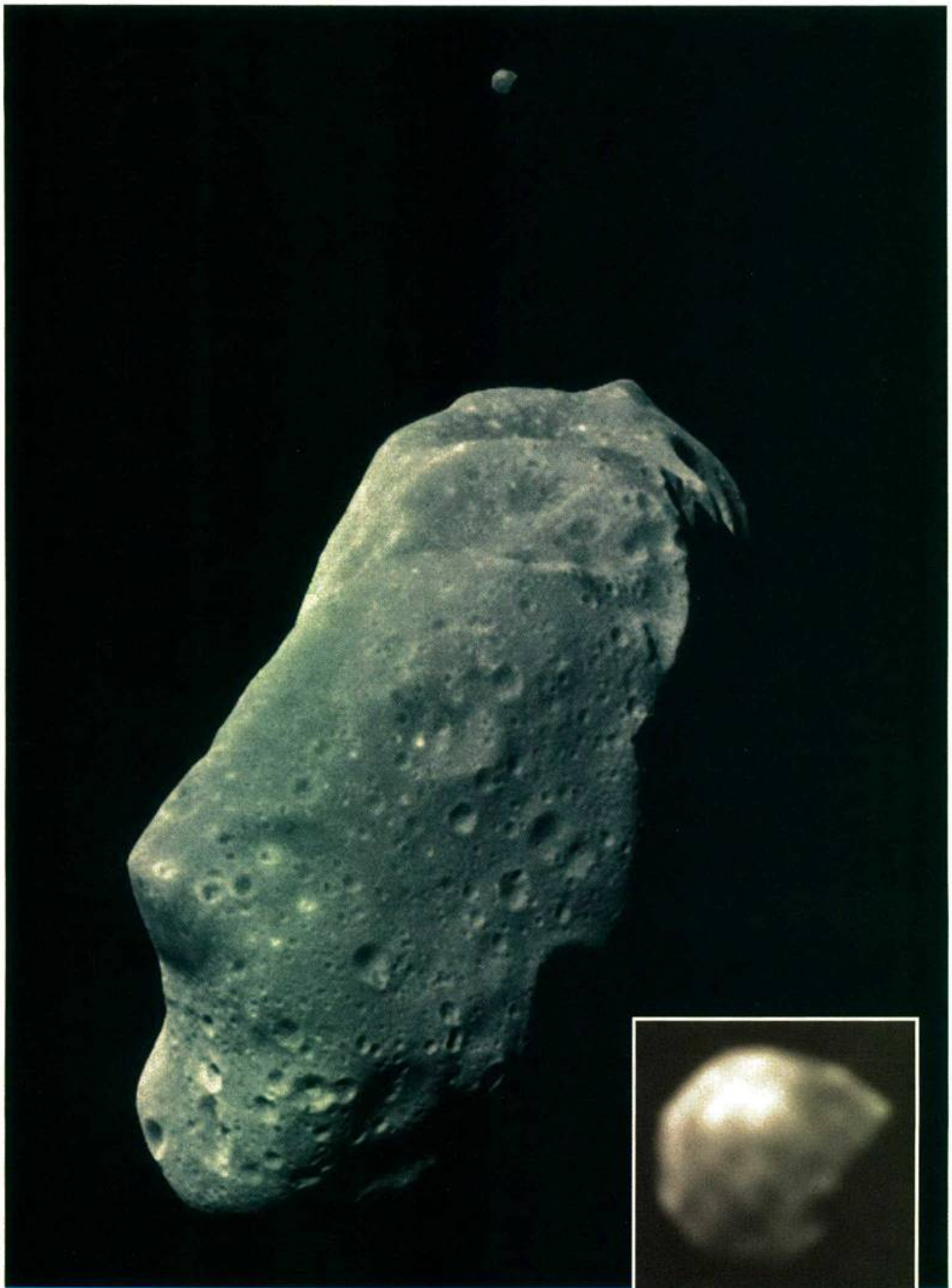

NASA/JPL

A NATURAL SATELLITE ORBITS the asteroid 243 Ida as revealed in images taken by the Galileo spacecraft on August 28, 1993. The moon, provisionally designated 1993 (243) 1 and nicknamed "Baby Ida" (top of image and inset), may be the remains of an object that struck Ida or a piece knocked loose from a collision. Baby Ida spans 1.5 kilometers and orbits Ida at a distance of 100 km. Forthcoming views will be three times sharper.

More Objects Discovered in Outer Solar System

Using a 2.2-meter telescope on Mauna Kea in Hawaii, David Jewett of the University of Hawaii and Jane Luu of the University of California at Berkeley discovered two more distant asteroids in our solar system. That brings the total of known outer solar system asteroids to ten. The two new objects are designated 1994 ES_2 and 1994 EV_3, the "E" in the names designating asteroids discovered in the first half of March 1994.

Both objects lie about 45 times farther from the Sun than does Earth and take about 300 years to circle the Sun once. The great distance from the Sun means that the bodies reflect little light back to Earth, making the asteroids glow dimly at 24th magnitude. In July, 1994 ES_2 lies a little less than 1° southeast of Rho Leonis and 1994 EV_3 is near the galaxy NGC 4951, which lies almost 7° northwest of Spica in Virgo.

A Lumpier Universe

A survey of galaxy motions out to a distance of 500 million light-years indicates that our Milky Way Galaxy and all its neighboring clusters of galaxies are drifting through space relative to extremely distant galaxy clusters. Tod Lauer of the National Optical Astronomy Observatories in Tucson, Arizona, and Marc Postman of the Space Telescope Science Institute in Baltimore, Maryland, performed the survey using telescopes at Kitt Peak in Arizona and at Cerro Tololo in Chile. Earlier studies had shown that our Galaxy and nearby clusters drifted as a group in the direction of the constellations Hydra and Centaurus toward a "Great Attractor" (see "Cosmic Tug of War," July 1993). But the new survey extends out two times farther than the

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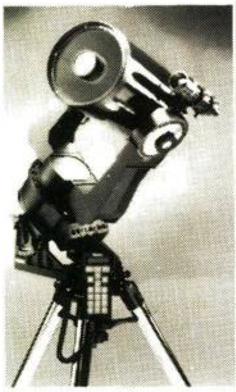

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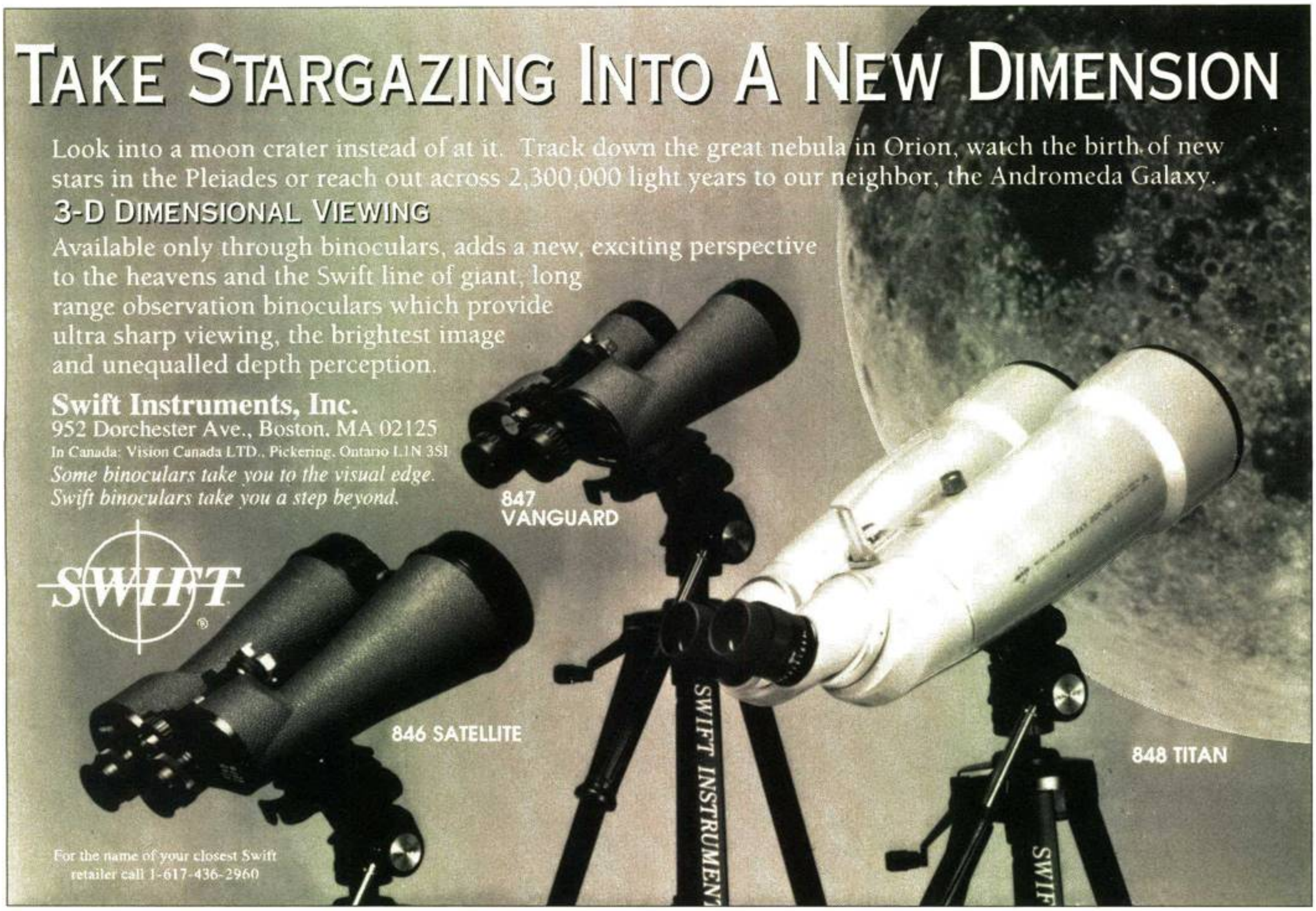


previous work, engulfing the Great Attractor deep inside the volume. So another source of the drift found in the survey must exist.

Lauer and Postman found the galaxies are rushing at almost 700 kilometers per second in the direction of Virgo. The only explanation is that large concentrations of matter are pulling the galaxies toward them. But current ideas hold that the universe is uniform over immense scales. The survey suggests that the universe is lumpier than astronomers imagine, containing structures a billion light-years across.

THE SPEEDING MOTIONS of the Coma cluster of galaxies (right) and other galaxy clusters toward Virgo recently revealed the gravitational tugs by huge structures in the universe.

National Optical Astronomy Observatories

AMATEUR NEWS

Tenth Winter Star Party a Success

Florida's annual Winter Star Party (WSP) had its 10th birthday this year. To celebrate, some 600 backyard astronomers from North America and Europe flocked to West Summerland Key on February 7, 1994, and enjoyed a week stargazing despite intermittent clouds.

The WSP originated in the active mind of Tippy D'Auria, who persuaded fellow members of the Southern Cross Astronomical Society in Miami to host a week-long star party. His reasoning was that the very dark skies in the Florida Keys, the exquisite seeing often present in the region, and the previous absence of star parties in the winter months would attract a gaggle of astronomy enthusiasts, particularly from the northern states. He was right.

Those who attended this year saw a large number of high-end apochromatic refractors and big Dobsonian reflectors. Although the well-equipped deep-sky nuts seemed to congregate in the "Valley of the Dobs," a fair variety of telescopes peppered the grounds of West Summerland Key's Girl Scout Camp. Probably the most impressive instrument at this year's WSP was Tom Clark's "Yardscope," so named because its mirror is an even yard across. The telescope provided superb images of the planets and deep-sky objects.

The incredibly steady seeing at the WSP site permitted amateurs to test the quality of a variety of large apo refractors, both commercial and homemade. Although southern winds occasionally carried in clouds, much of every night was clear. During these clear periods we had short spells of rock steady seeing. Using a 6-inch f/7 apo refractor, a group of us easily spotted six stars in the Trapezium, the multiple star at the heart of the Orion Nebula. The intensity of the fainter stars was stunning.

When not occupied watching stars, attendees marveled at Richard Berry's "cookbook" CCD camera, a homemade camera one can build for several hundred dollars. A. J. Sehgal displayed his maximum entropy deconvolution software on some CCD images, showing the amazing range of detail that can be pulled out of an ordinary looking image.

In a perverse attempt to deny attendees a reasonable amount of sleep, the organizers scheduled speakers throughout the afternoons.

The WSP organizers plan on holding the next WSP in February 1995 at the camp on West Summerland Key and expect a large turnout. — *Rick Shaffer*

Join Marswatch, See Another World

The availability of CCD cameras gives amateur astronomers opportunities to contribute to astronomical research. Planetary scientists Jim Bell (of NASA's Ames Research Center), Ken Herkenhoff (Jet Propulsion Laboratory/Caltech), and Leonard Martin (Lowell Observatory) are beginning a program of coordinated observations of Mars during 1994-1995. They call it the Amateur Marswatch Project.

They're seeking amateur astronomers who can use medium- to large-sized telescopes, CCD cameras, and color filters. The minimum capabilities needed for this project are the use of a standardized glass filter set and the ability to produce an image of Mars at a scale of approximately 0.3 arcsecond per pixel (this corresponds to a Mars image at least 50 pixels across at opposition).

The primary goal of the project is to image Mars at high resolution over all its surface. When combined with computer modeling, the data may allow scientists to accurately determine the amount and thickness of dust and ice clouds in the Martian atmosphere. It may also place limits on the abundances of certain surface minerals. Observations by amateur astronomers will be extremely useful in helping to expand the time coverage of the data, because professional astronomers typically have access to large telescopes for only a small fraction of the time during the apparition.

If you're an amateur astronomer interested in getting involved in a serious research effort, send a self-addressed, stamped envelope to Marswatch Project, c/o Jim Bell, NASA Ames Research Center, Space Sciences 245-3, Moffett Field, CA 94035-1000. You will be sent details and some explanatory literature on standardized observing techniques, filter costs and suppliers, standard star choices, data reduction techniques, and data archiving formats. You can get additional information on data taking and data reduction using CCDs by sending a self-addressed, stamped envelope to Donald Parker, 12911 Lerida St., Coral Gables, FL 33156.

Is There a Comet in Your Future?

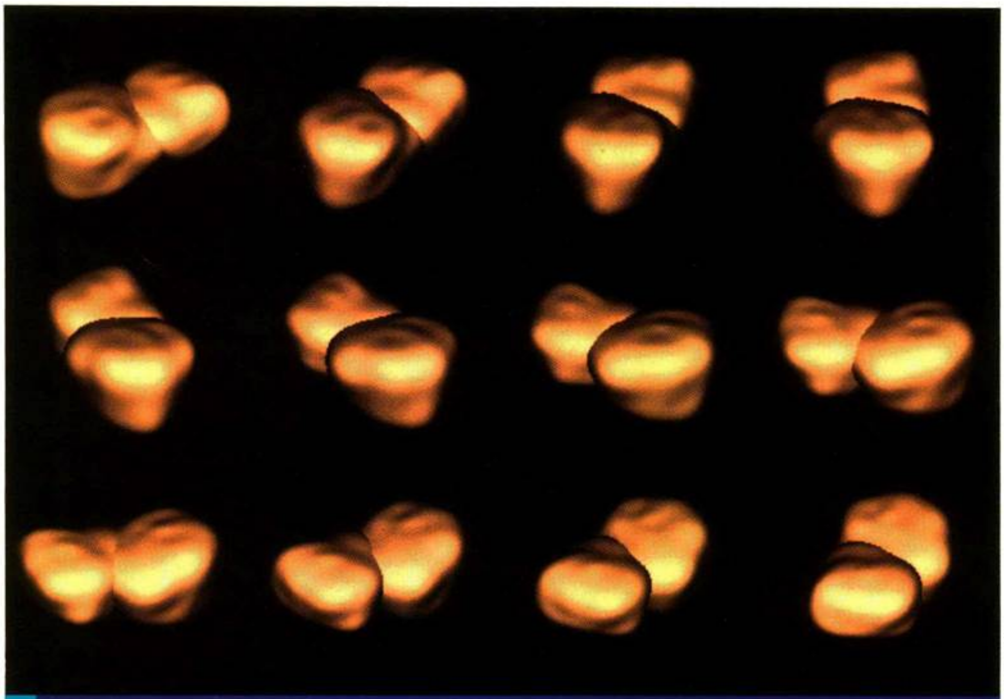
Don't say you haven't been warned: at this moment 100,000 comets may be bearing down on Earth, nudged our way thanks to the gravitational encouragement of Alpha Centauri. This is according to research published in the *Quarterly Journal* of the Royal Astronomical Society by Robert Matthews of the University of Aston, England.

Matthews figures that the Oort cloud, a spherical shell of dirty snowballs that extends out from the solar system about two light-years, may be feeling the gravitational effects of the Alpha Centauri system as it sweeps to within 3.12 light-years of Earth, traveling at 120,000 km per hour. These effects may provide enough of a jolt to start some comets on their long journey toward the inner solar system. He's also found that the Sun is entering a period of time rich in "close encounters" with other stars in its neighborhood. Matthews calculates no fewer than six stars will pass within 4.22 light-years of our solar system, each capable of stirring up trouble in the Oort cloud.

However, this bad news should be qualified, for these encounters will happen over the next 45,000 years. And those comets stirred up by Alpha Centauri? Matthews says they aren't scheduled to arrive for another 20 million years.

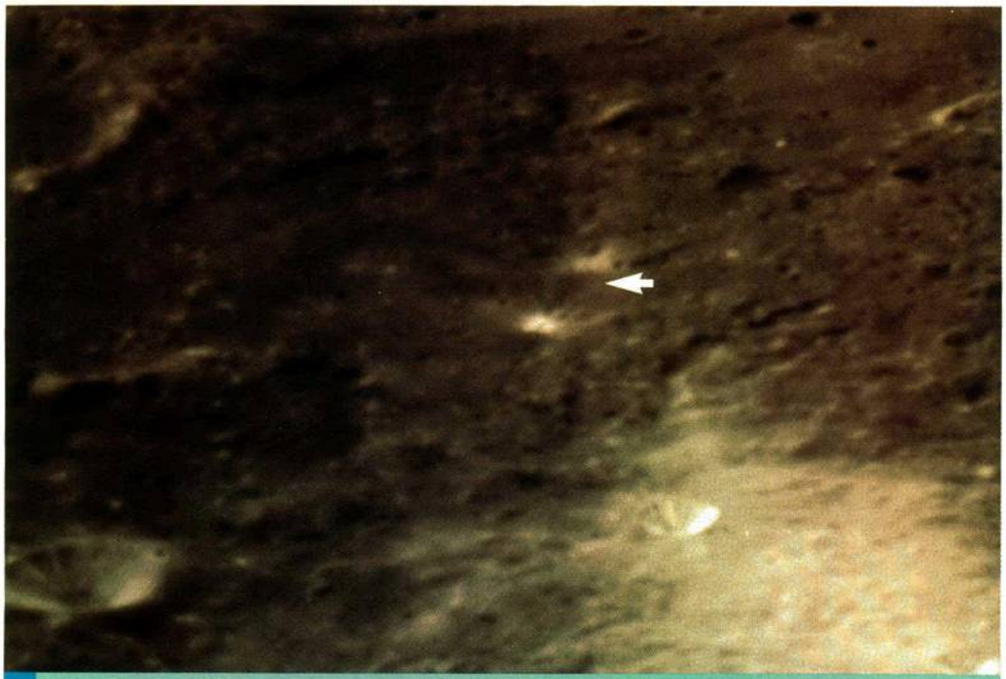
Supernova 1987A: More Action Ahead

Over seven years have passed since Supernova 1987A appeared in the Large Magellanic Cloud, becoming the first naked-eye supernova in nearly 400 years. After peaking at 3rd-magnitude three months after the explosion, the supernova began to fade and has continued to do so ever since. But now it appears that



JPL/NASA

ASTEROID 4769 CASTALIA has a double-lobed shape in this model constructed from the object's radar echos. Originally known as 1989 PB (see April 1990 issue, page 38), Castalia flew past Earth at relatively close range, letting Jet Propulsion Laboratory scientist Steven Ostro observe it by radar using the Arecibo radio telescope. Now R. Scott Hudson of Washington State University in Pullman working with Ostro has "inverted" the radar signals mathematically to determine the most likely shape for the asteroid. Each lobe is roughly 1 km in diameter and the crevice between them is 100 to 150 meters deep.



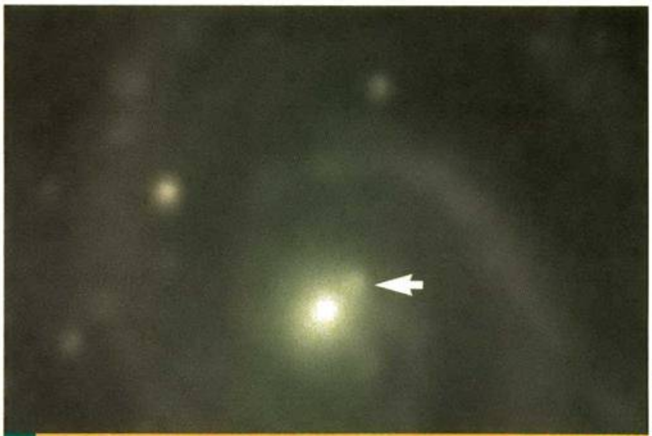
NRL/Department of Defense

THE LANDING SITE OF APOLLO 16 appears between North Ray and South Ray crater (arrow), but the resolution of the Clementine UV/Visible camera image is a bit too low to reveal the lander. At the bottom is a 49-km-wide crater called Almanon, and the bright spot below the arrow marks the crater Descartes.

the supernova is on the threshold of re-brightening (see "Will Supernova 1987A Shine Again?" February 1992).

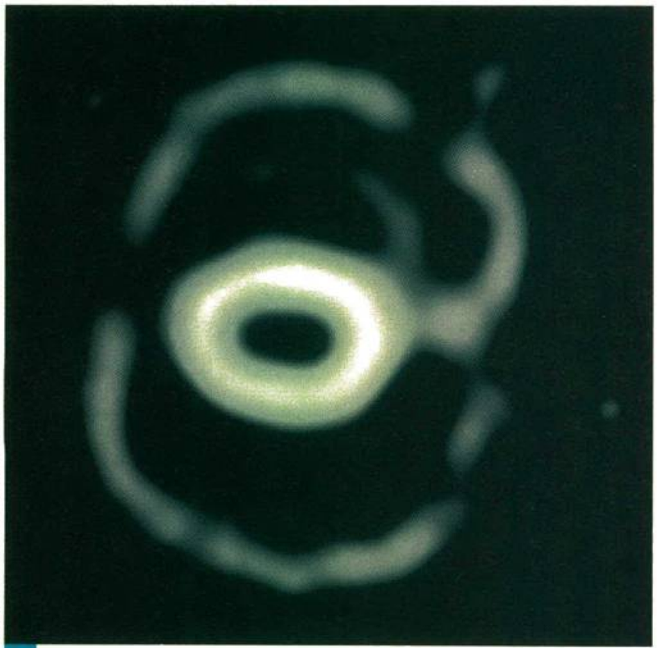
Astronomers Li-Fan Wang of Beijing University and E. Joseph Wampler of the European Southern Observatory have discovered that the nebula surrounding 1987A has begun to brighten slightly in several spots. Observing with ESO's 3.6-meter New Technology Telescope in La Silla, Chile, the two found the changes when comparing images taken in December 1993 with those from the previous two years.

The nebula, which forms a ring around the site of the supernova, is a relic of the exploded star dating from before the explosion. That star spent most of the last million years of its life as a red supergiant, blowing a slow wind of material into the surrounding space. But for the last 100,000 years of its life, the star was a blue supergiant with a much faster wind. The material in the blue supergiant's wind plowed up that from the red supergiant's wind, creating the ring. Now the debris from the supernova itself — rushing outward at one-tenth the speed of light — is catching up to the pre-existing ring and causing it to brighten. Further observations show that the vast majority of the explosion's debris has yet to reach the ring, but the collision has at least begun. Supernova 1987A will bear close watching over the next few years.



Richard Berry

A BRIGHT SUPERNOVA (arrow) appeared in the galaxy M51 in Canes Venatici on April 1, 1994. Discovered by amateur astronomers in California, Georgia, and Wisconsin, Supernova 1994I was still brightening at press time. Richard Berry's sequence of 66 CCD frames made on April 1 documents its earliest detectable rise in brightness. See the August issue of ASTRONOMY for more details on SN 1994I.



European Southern Observatory

THE INNER RING AROUND SUPERNOVA 1987A has brightened slightly, hinting that stellar debris from the explosion seven years ago has begun hitting the ring's gases. The image reveals the brightening as uneven structure in the inner ring. Both the bright inner ring and faint outer ring were created before the star exploded. The supernova itself, which lies at the center of the ring, can't be seen because it emits very little light in the narrow spectral band used to make the image.

New Proof of Quasar/Galaxy Link

The discovery of large amounts of iron in two very distant quasars supports the idea that these highly luminous objects lie at the centers of massive galaxies and implies that they are at least one billion years old.

Richard Elston of Cerro Tololo Inter-American Observatory in Chile, Keith Thompson of the Naval Research Laboratory in Washington, D. C., and Gary Hill of McDonald Observatory in Texas observed the quasars Q 0014+813 and Q 0636+680. These objects have redshifts of $z = 3.4$ and $z = 3.2$, respectively, meaning that the wavelengths of lines in their spectra have been shifted toward longer wavelengths by those factors. To produce redshifts this high, the quasars must be receding from Earth at about 90 percent the speed of light.

In the January 20, 1994 issue of *Nature*, astronomers report that both quasars have an iron abundance many times higher than that in the Sun's neighborhood, which implies that the quasars' host galaxies must produce many type Ia supernovae. (A type Ia occurs when a white dwarf in a binary system accretes enough of its companion's atmosphere that it becomes unstable and explodes, destroying itself and spewing large amounts of iron into its surroundings.) The large number of supernovae requires dense stellar regions, just what is expected in the center of a massive galaxy.

A more exciting point raised by the high iron abundance is the age of the universe at these redshifts. It takes about a billion years to enrich a quasar's host galaxy with iron by forming and exploding white dwarfs. But the age of the universe at $z = 3.4$ is only 700 million years, if the universe is flat and the Hubble constant is 31 km/sec/million light-years. So these observations imply that the Hubble constant is less than 31, the universe is open, or both. The researchers plan to study even higher redshift quasars to try to pin down these cosmological parameters.

A Black Golf Ball in Space

Eight years after passing close to the Sun, periodic Comet Halley lies almost 3 billion km from our star or at about the distance of Uranus. This distance is halfway to the farthest point in Halley's 76-year orbit around the Sun. Astronomers at the European Southern Observatory in Chile captured Halley at the halfway point using the 3.6-meter New Technology Telescope. Their image reveals just the comet's frozen nucleus with no sign of a gas or

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dust cloud surrounding the body. The surface of the comet appears to have completely ceased emitting gas and dust. ESO scientists witnessed an outburst of a million tons of gas and dust from Halley as recently as February 1991 (see AstroNews, October 1991).

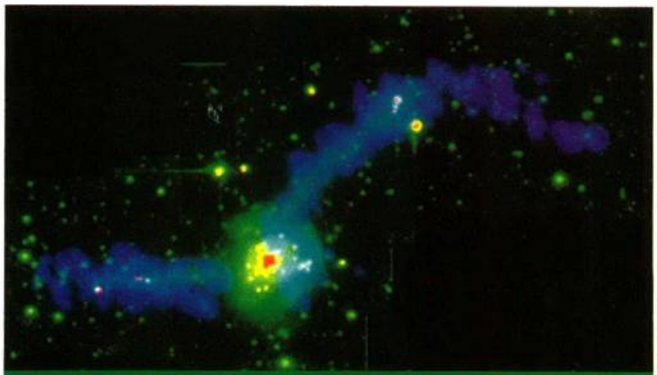
European Southern Observatory

COMET HALLEY IS HALFWAY to the farthest point in its orbit, now lying about as far from the Sun as Uranus.

Not only was this the most distant observation of Halley ever made, it was also the faintest, with the comet appearing at magnitude 26.5. Viewing the 6 km by 15 km nucleus is like viewing a black golf ball at a distance of 12,000 km during an evening game, so imaging the comet required a lengthy 4-hour exposure. ESO astronomers plan to continue their monitoring efforts of Halley, just in case another outburst occurs, perhaps using the 8.2-meter Very Large Telescope now under construction.

Seeing the Seeds of Today's Cosmos

Astronomers studying the cosmic background radiation from the ground have for the first time identified individual features in the background. These features, which appear as tiny fluctuations in the temperature of the background radiation, mark regions of slightly higher density that formed the seeds for the large-scale structure we see today in the universe.



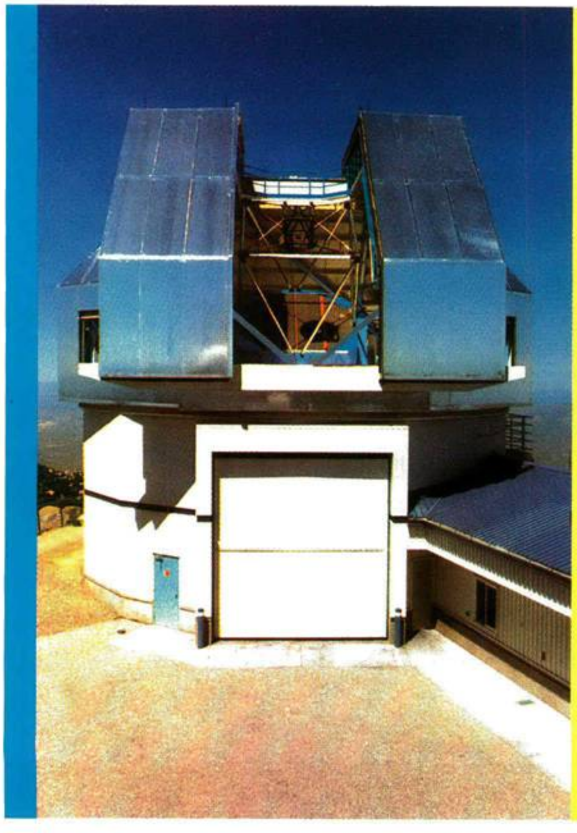
John E. Hibbard, Columbia University et al.

STRANGERS IN THE NIGHT, two galaxies passing each other collided and merged to form the gas-rich elliptical NGC 7252 in Aquarius. This false-color image shows the galaxy's nucleus (center) and two enormous tails of matter left from the galaxies' collision. Blue represents neutral ..hydrogen gas and red ionized hydrogen.

The first evidence for temperature fluctuations in the background radiation came in data returned in an all-sky survey by the Cosmic Background Explorer satellite (see "COBE's Big Bang," August 1992). But individual fluctuations in the COBE data were buried in instrumental noise. The signal was statistically significant, but you couldn't point to any one part of the sky maps and say "That's a primordial temperature fluctuation."

Now a team of astronomers led by S. Hancock of the University of Manchester in England used three radiometers located on Tenerife in the Canary Islands to observe a 360° strip of right ascension at a fixed declination of 40°. They then analyzed in detail the region of Ursa Major, Canes Venatici, and Bootes, where radio emission from the Milky Way Galaxy interferes the least.

They report in the January 27, 1994 issue of *Nature* that they found fluctuations of about 40 millionths of a kelvin in the overall 2.73 kelvin background. The size of the fluctuations confirms the statistical detection by COBE but increases the angular resolution from COBE's 10° to 4°. However, the fluctuations they see do not correspond to any structures seen today, the largest of which would be no more than about a degree across at the scale of the background radiation. A half-dozen other teams of researchers, in addition to the Tenerife group and COBE scientists still analyzing their satellite data, continue to observe and analyze the background radiation in the hopes of better understanding how the universe formed large-scale structures. □



THE WIYN TELESCOPE JOINS a dozen other major telescopes on the top of Kitt Peak, located southwest of Tucson. The 3.5-meter scope, built by the University of Wisconsin, Indiana University, Yale University, and the National Optical Astronomy Observatories, has pioneered several new technologies for mounting the mirror and moving the telescope on an altazimuth mount.

Mark Hanna, NOAO

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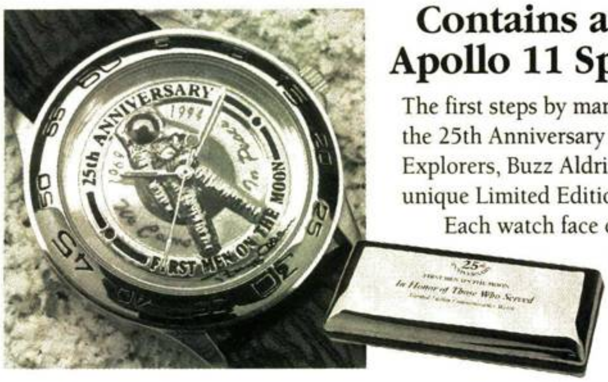

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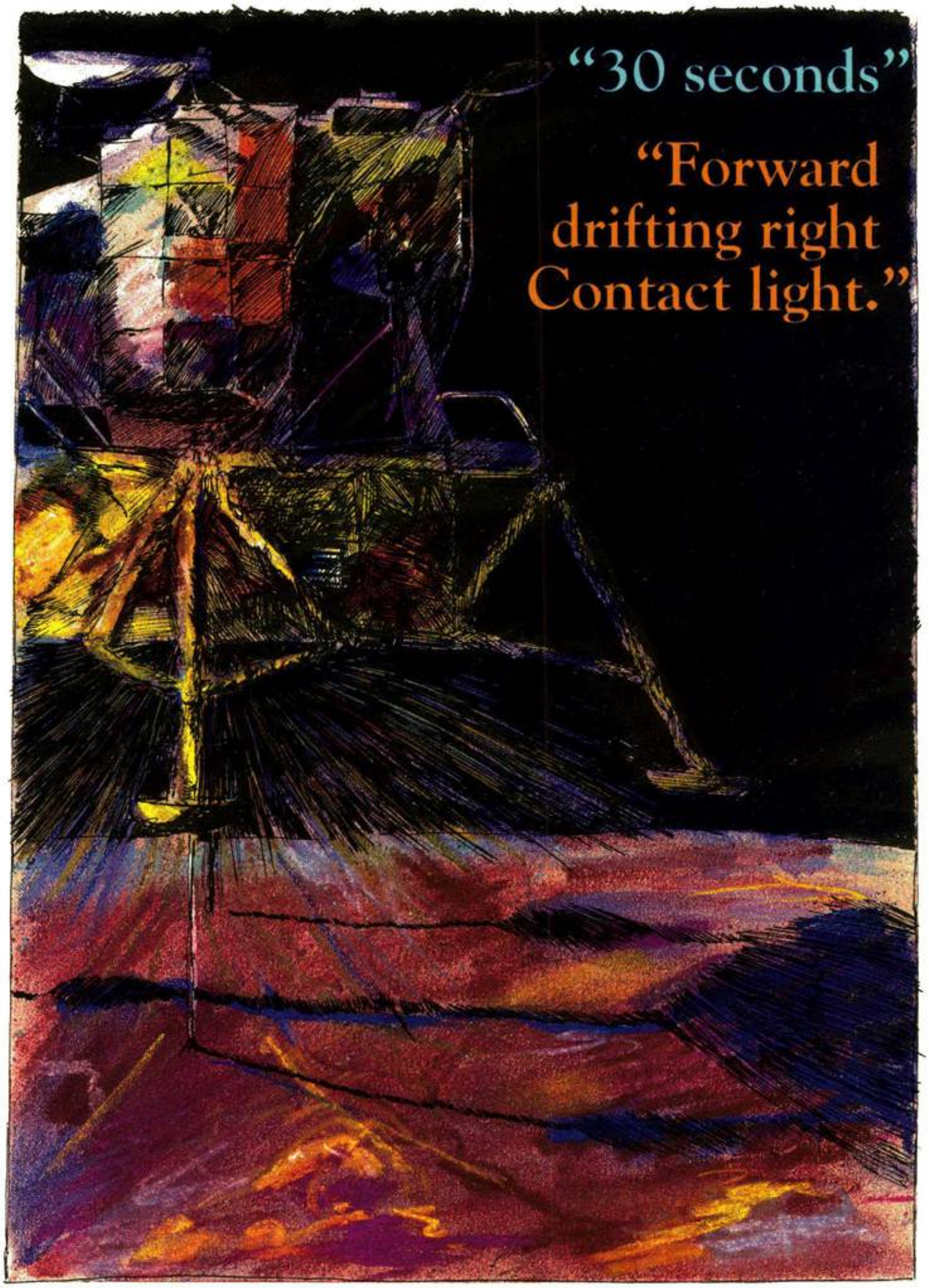
The Moon



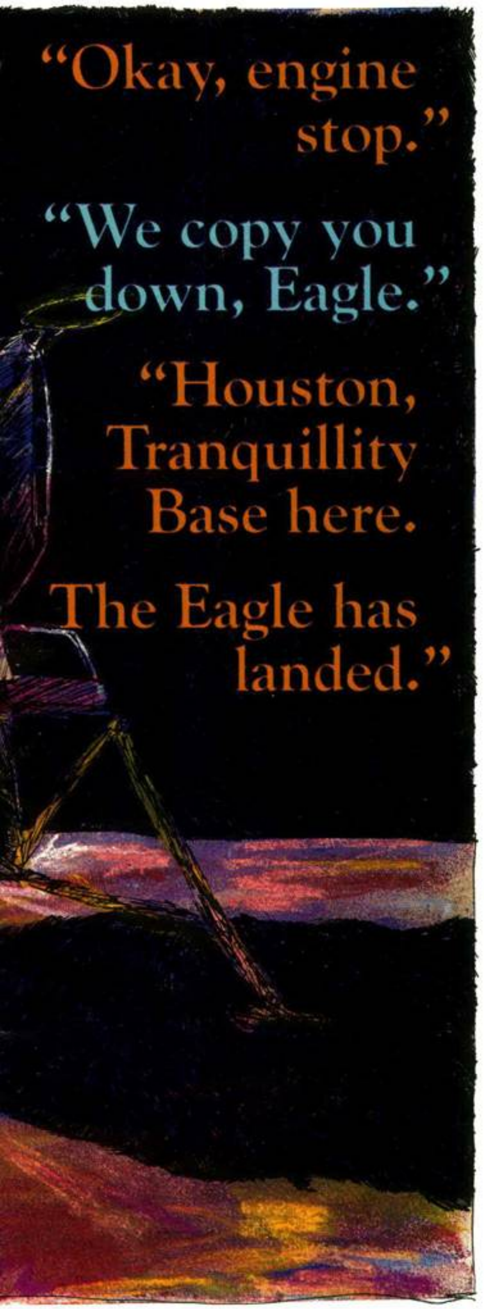
"30 seconds"

"Forward drifting right Contact light."

Voyagers

APOLLO 11 25th Anniversary

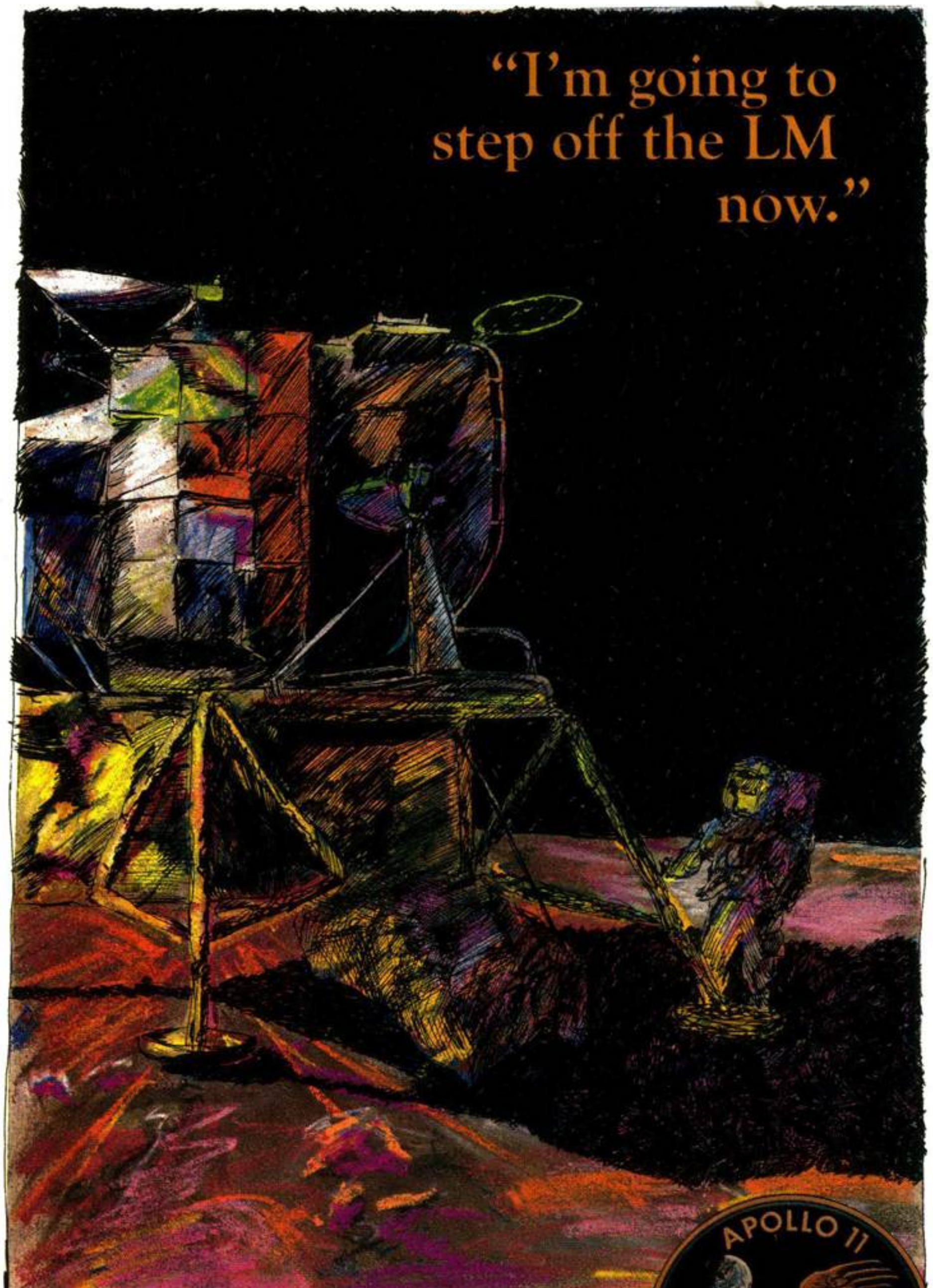
by Andrew Chaikin



"Okay, engine stop."

"We copy you down, Eagle."

"Houston, Tranquillity Base here. The Eagle has landed."



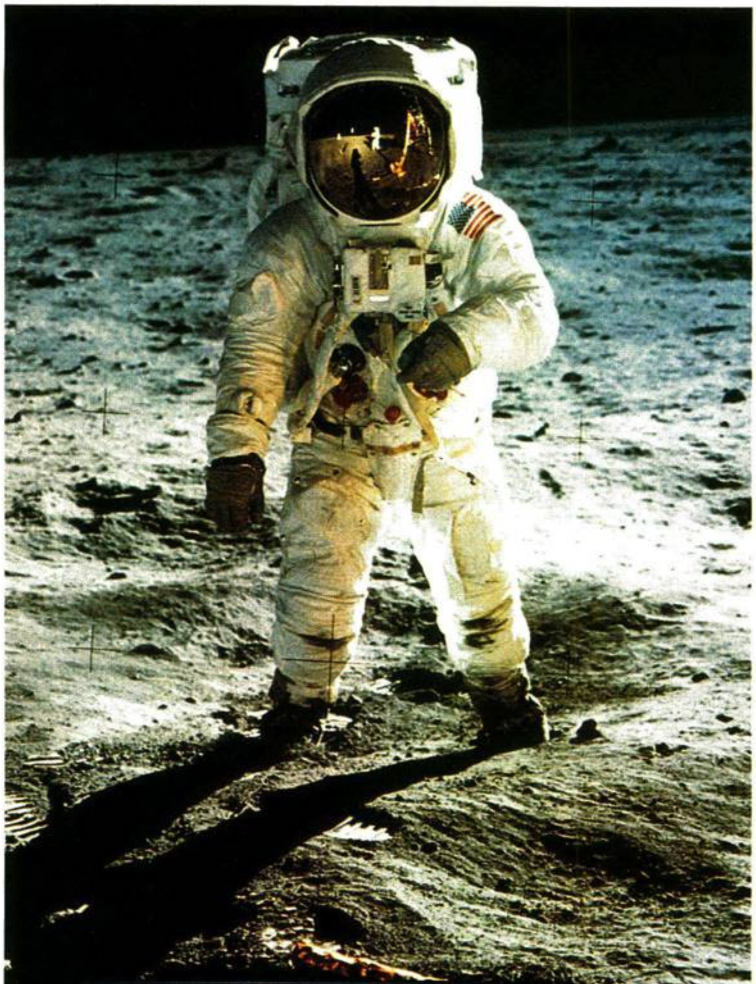
"I'm going to step off the LM now."

Illustrations by Thomas L. Hunt

"That's one small step for man, one giant leap for mankind."

NASA

One of the most quietly electrifying experiences of the late 20th century — if we take the time to have it — is to go outside, look at the Moon, and realize that men have been there. Even now, a quarter century after Apollo 11 astronauts Neil Armstrong and Buzz Aldrin made the first moonwalk on July 20, 1969, it is hard to comprehend.



Neil Armstrong Michael Collins Edwin Aldrin

All photos by NASA

> **"Here men from the planet Earth first set foot upon the Moon, July 1969, A. D. We came in peace for all mankind."**

In May 1961, President John Kennedy had challenged the nation to land a man on the Moon and return him safely to Earth by the end of the decade. Just over eight years later, it happened. In all, 24 men journeyed to the Moon in nine flights (three astronauts flew two missions each), and six pairs of astronauts explored the lunar surface. This is the story of those journeys — the explorations and the once-in-a-lifetime experiences — seen through the eyes of some of the men who participated in this grand adventure.

Leaving

On December 21, 1968, a voyage unprecedented in the history of exploration began: Apollo 8 astronauts Frank Borman, Jim Lovell, and Bill Anders rode a giant Saturn V booster into orbit and then, re-igniting the Saturn's third-stage engine, became the first humans to break free of Earth's gravity. Although the Apollo 8 crew would only orbit the Moon and not land on it, most people who worked on Apollo say that this initial mission to our satellite was the high point of the program.

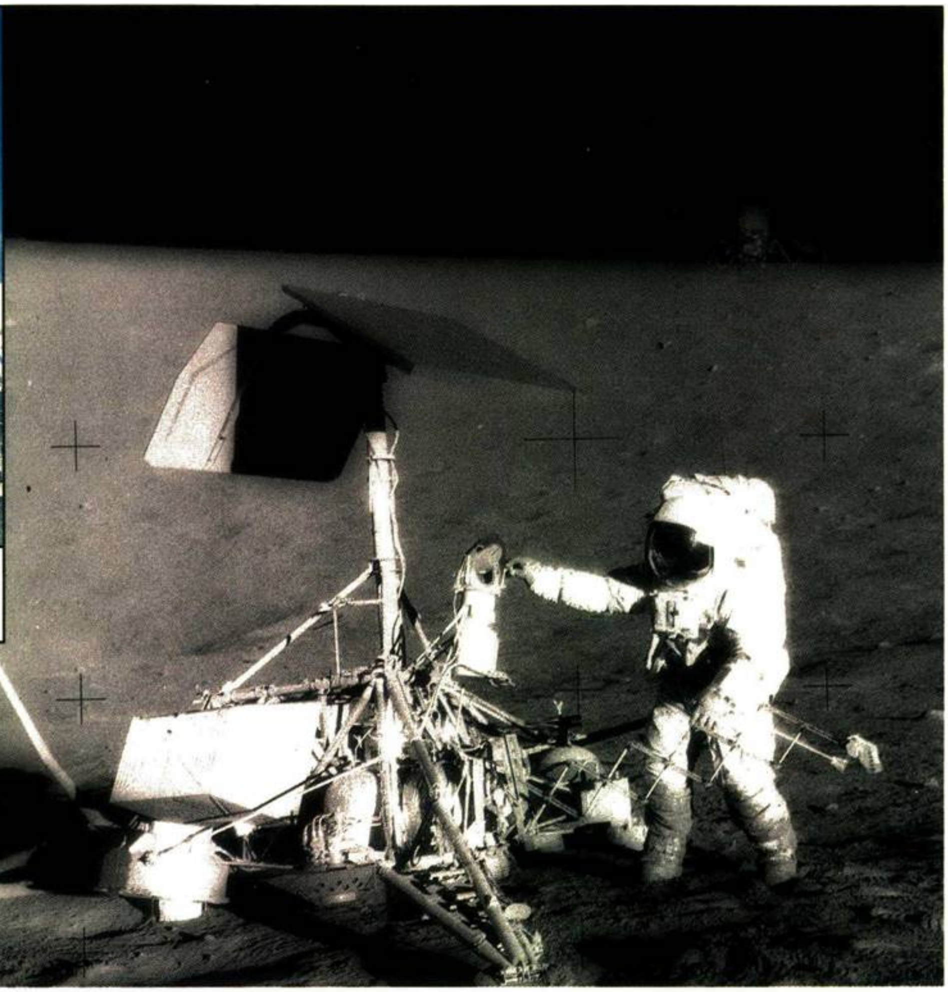
This bold venture came just two years after Apollo's darkest hour: On January 27, 1967, astronauts Gus Grissom, Ed White, and Roger Chaffee were killed on the launch pad by a flash fire inside their Apollo 1 command module. By the summer of 1968, a redesigned, fireproof command module was undergoing final testing. But the lunar module, or LM (pronounced "lem"), designed to ferry astronauts from lunar orbit down to the surface and back to the command module, was way behind schedule due to technical problems. To keep Apollo's schedule from slipping too far, mission planners decided to fly Apollo 8 into lunar orbit with just a command module and no LM.

Soon after the third-stage engine shut down, mission commander Borman cut Apollo 8 loose from the booster and turned the craft around. The men could then see the world they left behind, not a landscape but a *planet*, afloat in a blackness so deep as to be unimaginable. On this glittering sphere, amid deep blue oceans and white streamers of clouds, patches of vivid orange and tan marked the planet's desert regions. The jungles and temperate zones appeared bluish gray. At first, Apollo 8 was moving away so rapidly that the men could almost see their world dwindle as they watched. Later, as Earth's gravity slowed their departure, it was more like watching the hands of a clock move: If they turned away from the window for a few minutes and then looked at Earth once more, they noticed it was a little smaller and more distant.

Inside Apollo 8, rookie astronaut Bill Anders got his first taste of weightlessness and savored a freedom he had never known. He moved within the cabin by his fingertips. Flashlights and cameras twirled and tumbled in midair. Blobs of water became shimmering spheres. But Anders would later describe the trip out to the Moon as "a bit of a drag," in part because of Frank Borman's brief bout with motion sickness.

In addition, the view didn't live up to Anders' expectations. Of the three men, he had spent the most time studying lunar geology, using photographs from the unmanned Lunar Orbiter probes. But he had not seen the Moon once on the trip out. He'd expected to see it growing ever larger as Apollo 8 closed in, like a science-fiction vision. Instead, because of the angle of their approach, it was lost in the Sun's glare. Outside,

Charles Conrad, Jr. Alan Bean
Richard Gordon, Jr.



"Boy, you'll never believe it. Guess what I see sitting on the side of the crater? The old Surveyor."

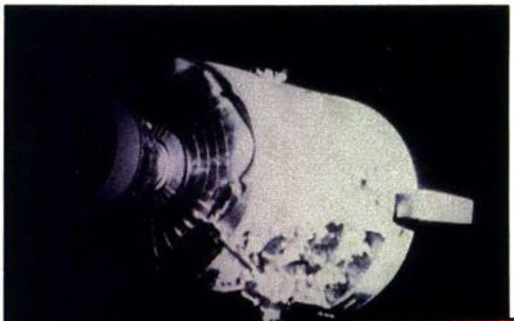
XII

he saw only a dull, starless black.

In the early morning hours of Christmas Eve, 1968, Anders and his crewmates strapped themselves into their couches and prepared to fire their rocket engine to go into lunar orbit. Suddenly Apollo 8 flew into total darkness. For the first time in the flight the sky was full of stars, more than Anders had ever seen on the clearest nights on Earth. He craned toward the side window to look in the direction they were headed and noticed a distinct arc beyond which there were no stars at all, only blackness. All at once he was hit with the eerie realization that this hole in the stars was the Moon. The hair on the back of his neck stood up. He gave himself a silent reprimand: *Come on, Anders. You're not supposed to feel this way.*

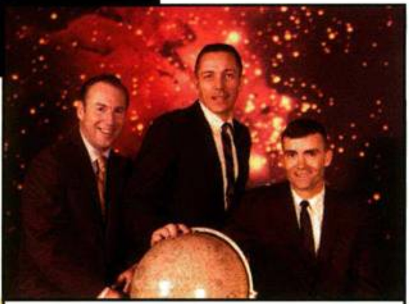
Minutes later Apollo 8 was in lunar orbit, and Borman's crew looked down at a scene of utter desolation, like the deserted battlefield of the final war. Seen from Earth on December 24, the Moon was a ripening crescent. Much of the near side was in darkness, while well over half of the Moon's hidden face, never before seen by human eyes, was in sunlight. It was Anders' job to capture on film as many craters and other lunar features as he could, and during most of the 20 hours Apollo 8 spent in lunar orbit, he was hard at work observing and photographing the pockmarked landscape beyond his windows.

But the most electrifying sight of all came during the fourth orbit, after Borman had turned the spacecraft and Apollo 8 drifted over the boundary between the farside and nearside. Suddenly Anders looked out his window and what he saw almost took his breath away: The



"Okay, Houston, we've had a problem here."

XIII



John Swigert, Jr.
James Lovell, Jr. Fred Haise, Jr.

Earth, now a radiant blue and white marble, rising beyond the battered face of the Moon. Anders' photograph of the first Earthrise (see page 4) has become one of this century's most famous images. While still in lunar orbit, Anders began to realize, *We came all this way to explore the Moon, but the most important thing we discovered was the Earth.*

Flying

Like most of the Moon voyagers, Apollo 12 astronaut Charles "Pete" Conrad fell in love with airplanes at an early age. After graduating from Princeton, Conrad became a Navy fighter pilot and moved quickly into the ranks of the top fliers in the country. In 1962, by then a seasoned test pilot, Conrad was selected by NASA as an astronaut. He had no innate desire to go to the Moon. If NASA had wanted to build a permanent space station in Earth orbit, Conrad would have been just as happy to do that. But John Kennedy had said, "We choose to go to the Moon" — and when the Moon became NASA's goal, it became Conrad's. At NASA, Conrad spent seven years waiting for his chance to land on the Moon — first as a rookie astronaut and then as a veteran of two Gemini Earth-orbit missions. He knew the Apollo missions would be the most complex, challenging test flights of all time.

As it turned out, there wasn't much flying to do on the lunar missions, not in the strict sense. The command module and lunar module had onboard computers that, although primitive by today's standards, were still powerful enough to function as a fourth crew member. During maneuvers, the computer turned the rocket engine on and off at the proper moments and steered the craft onto the correct flight path.

To be sure, the astronauts had more than enough to do operating the many systems aboard the command ship and the lander, making navigation sightings and, of course, making observations of the Moon and Earth. But the only real "stick time" came in the most critical and most demanding phase of the mission: the final descent to the lunar surface. The so-called Powered Descent was really a controlled fall from orbit beginning 50,000 feet above the Moon and lasting about 12 minutes.

Because the LM had enough fuel for only one landing attempt, the Powered Descent was another task reserved for the computer. But in the last few hundred feet, the astronauts took over control — not just because as self-respecting pilots they weren't about to let a computer make the landing but because the computer was blind; it had no way of avoiding craters and

APOLLO 14
Shepard
Ro

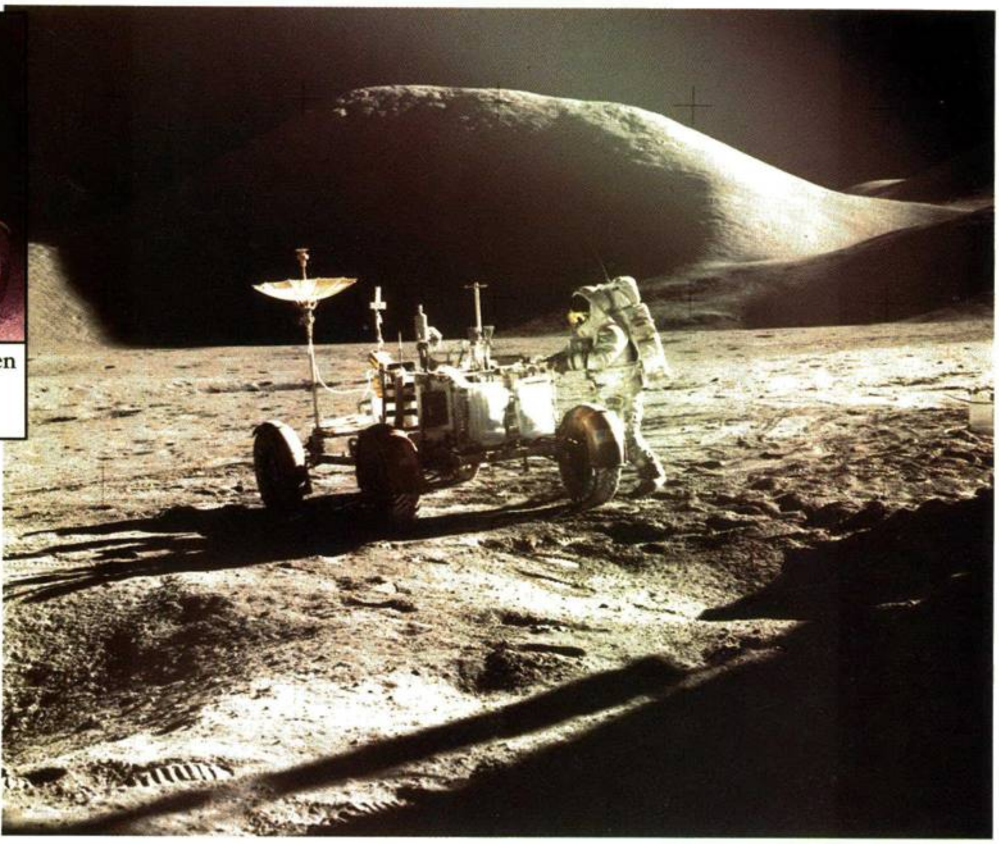
Alan Shepard

Stuart Roosa Edgar Mitchell

"Okay Al, beautiful. We can see you coming down the ladder right now. . . . And on the surface. Not bad for an old man."

"Okay, you're right. . . . It's been a long way, but we're here."

Alfred Worden
David Scott
James Irwin



"All of the features around here are very smooth. The tops of the mountains are rounded off. There are no sharp jagged peaks or no large boulders apparent anywhere."

boulders. The mission commander's moment of truth came in the lander's tiny cabin, steering the craft to a touchdown.

Pete Conrad's moment came on November 19, 1969, as he and his old Navy buddy, Alan Bean, descended to the Ocean of Storms in the lunar module Intrepid. Their mission was to touch down within walking distance of the unmanned Surveyor 3 probe, which had landed on the Moon in 1967. In doing so, they would test the pinpoint landing capability crucial to future lunar explorations. It was pointless to have scientists painstakingly choose landing sites if there was no certainty of getting there.

Seven thousand feet above the Moon, right on schedule, Intrepid pitched forward for its final descent. Suddenly a bright moonscape swung into view, and Conrad peered through his small, triangular window at thousands of craters. Somewhere among these pockmarks was the crater in which Surveyor 3 sat. Sighting through a special grid, Conrad saw where the computer was taking him: right to the center of the Surveyor crater. Conrad couldn't contain himself. *"Hey, there it is,"* he told Bean. *"There it is! Son of a gun, right down the middle of the road!"*

Meanwhile as the computer flew Intrepid lower, Conrad saw that the preplanned landing area was a battlefield of craters. At 400 feet Conrad took over, experiencing a type of flying entirely different from anything he'd known in airplanes. Intrepid was balanced on the thrust of its rocket engine like a dinner plate on a magician's broomstick. To change direction, Conrad had to tilt the craft to one side, being careful not to tilt too far or for too long. The craft responded sluggishly, but to Conrad it was all familiar because of practice sessions on Earth using a special rocket- and jet-powered trainer. Flying the trainer was so risky that NASA managers questioned its use, but to Conrad and the other mission commanders, it was essential.

Having found a smoother landing spot, Conrad began his final, vertical descent to the surface, now 200 feet below. Exhaust from Intrepid's rocket engine created a dust storm that obscured the surface. As he brought Intrepid lower, Conrad's eyes went back and forth from the window to the gauges on the instrument panel. It was the worst possible way to fly, with his attention split, but he had no choice. Finally, he heard Bean announce, "Contact light!" Metal probes attached to Intrepid's landing gear had touched the Moon. Immediately Conrad shut down the engine, and the lander fell the final few feet to the ground with a firm thud. Conrad had logged a grand total of 90 seconds of stick time, but he would say later that it took every ounce of experience from 20 years of flying to get Intrepid down safely. When Conrad stood at last on the surface of the Moon, the first thing he did was to walk past the foil-covered bulk of his lunar module and look to the east. There, 600 feet away, on the slope of a vast, worn crater, was Surveyor 3.

For Conrad, as for the other five mission commanders who made lunar landings, the moment of touchdown filled him with the greatest euphoria of the mission. Even Neil Armstrong, whose first lunar footstep created great anticipation in the months before Apollo 11, says that it was the moment when he and Buzz Aldrin landed that for him represented the first human contact with the Moon, not his famous footstep more than six hours later. But from Apollo 12 on, landing on the Moon was no longer the most important goal of the mission. Now the emphasis shifted to what the astronauts would do when they got there.

Walking

Anyone who watched television on the night of July 20, 1969, remembers the ghostly black and white images of Neil Armstrong's space-suited form descending the ladder of the lunar module Eagle and taking the first steps on another world. The sensation of walking in the Moon's one-sixth gravity was almost familiar to him, in part because of hours spent aboard NASA's KC-135, a special training aircraft that could create about half a minute's worth of simulated lunar gravity by flying along a parabolic arc. Nevertheless, as Armstrong took his first steps, he moved with the halting gait of a man learning to walk again. Encased in his pressurized suit, it was difficult to bend at the knees, and movement came mostly from the ankles and toes.

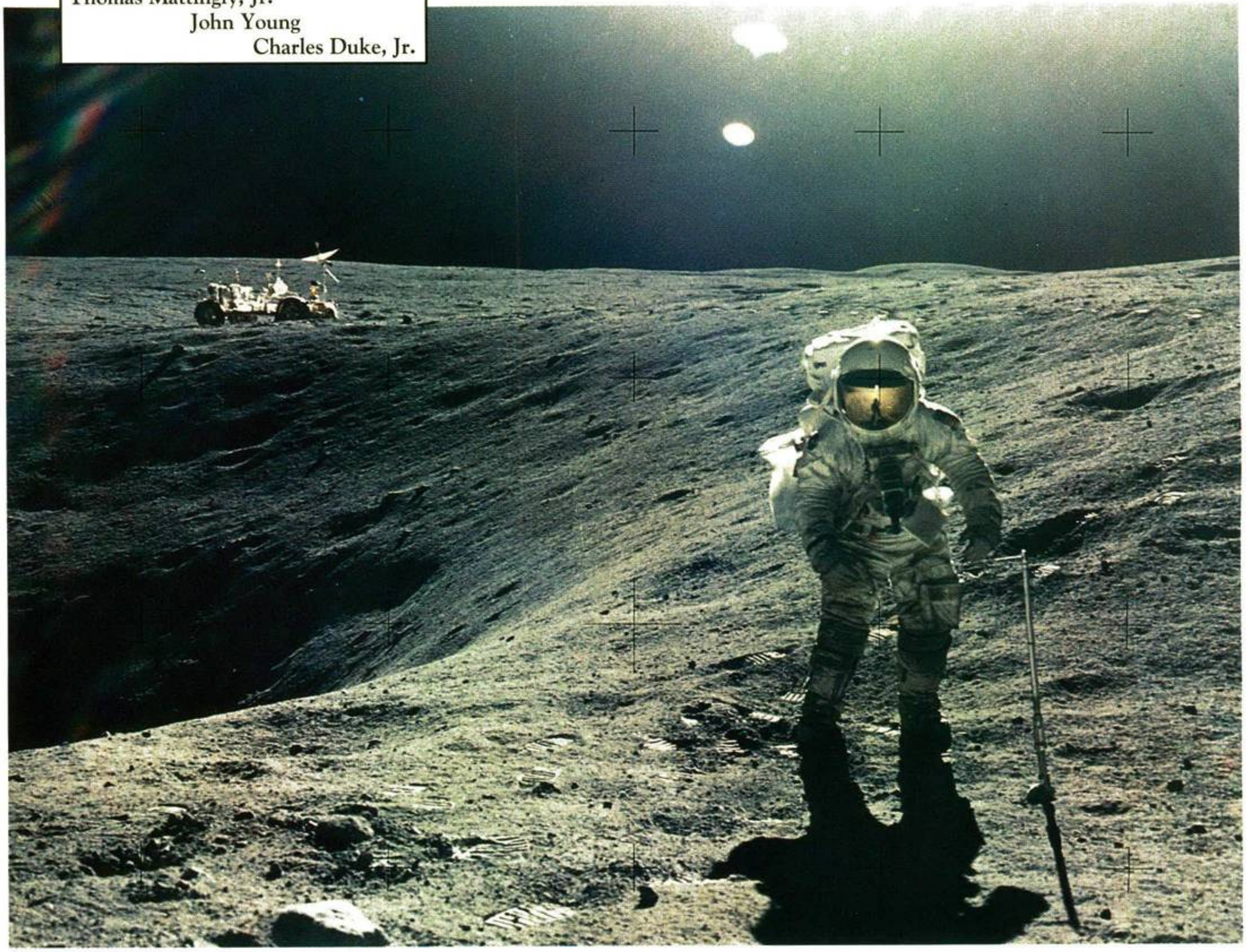
XVI

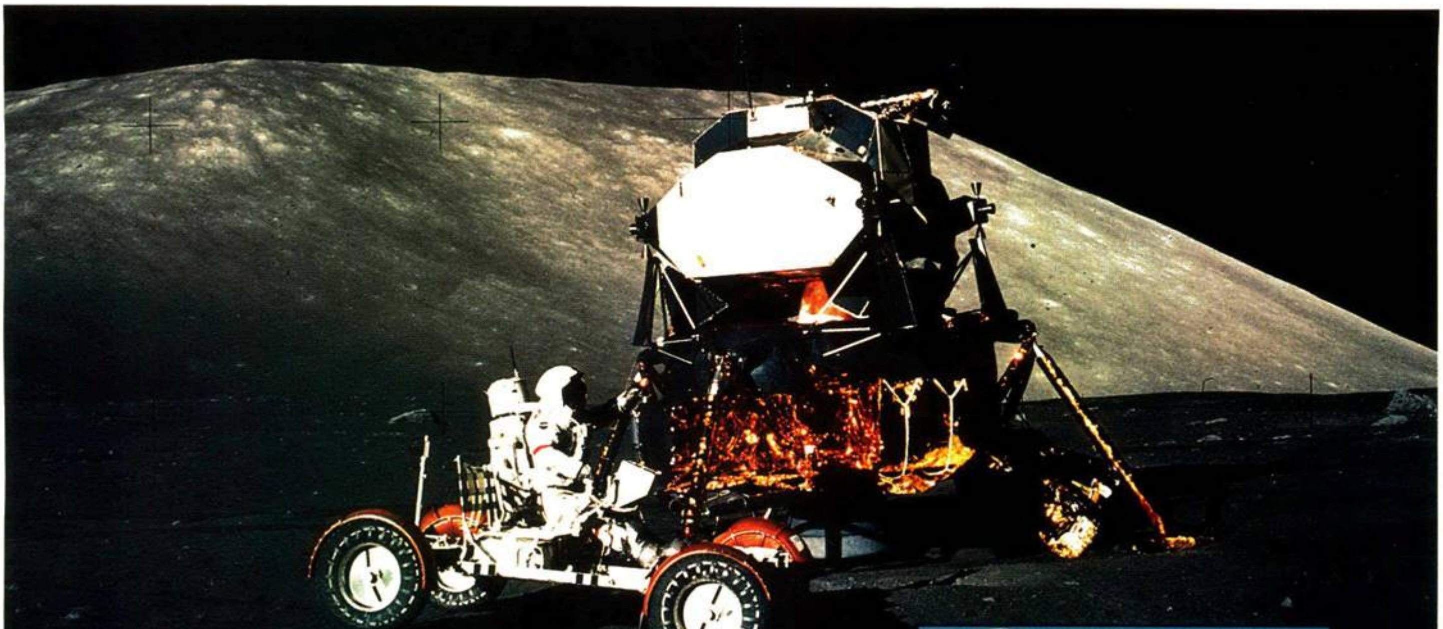
> **"Cayley Plains? There's nothin' 'plains' about this place. There's just craters on top of craters."**

Thomas Mattingly, Jr.
John Young
Charles Duke, Jr.

The ground under his feet was covered with a layer of fine dust that clung like soot to his boots and the legs of his space suit. Armstrong was fascinated at how crisply it took the imprints of his boots, but he was even more awed by what he saw all around him: the lava plains of the Sea of Tranquillity. Their stark beauty reminded him of the high desert of California's Edwards Air Force Base — but here was the ultimate desert, complete in its stillness and its starkness.

In the lunar void, everything was unnaturally clear. Boulders at the horizon looked as sharp as the rocks just beyond Eagle's footpads. Most fascinating, the ground's appearance changed depending on which direction





Harrison Schmitt Ronald Evans

Eugene Cernan

"Can't see the rear [wheels] but I know the front ones turn and it does move. Houston, Challenger's baby is on the road."

XVII

Armstrong looked. Facing due west, the light of the rising Sun was thrown back at him by a bright tan plain that on either side gave way to a dimmer, grayer tan. When he looked to the north or south where the land was crisscrossed with morning shadows, he saw a darker ashen gray. And when he had filled a small sample bag with lunar dust and held it in his hand, the mystery of the Moon's changing colors deepened: The soil in the bag was almost black.

Within minutes, Aldrin joined Armstrong on the surface to make his own exploration. His eyes immediately went to his feet, where each step raised a spray of particles that moved away in perfect, umbrella-shaped arcs. Looking around, Aldrin saw that the land curved noticeably away from him. Because of the Moon's small size, the horizon was much closer than on Earth — only a mile and a half away. Just beyond, as empty as the edges of a 15th-century map, was the blackness of space.

It was characteristic of the conservatism of the first landing that Armstrong and Aldrin made only one moonwalk, and it lasted about as long as a feature-length film. The astronauts of the next two landings, Apollos 12 and 14, took two moonwalks, each lasting just under four hours. (Apollo 13 was aborted following the explosion of an oxygen tank 200,000 miles from Earth.) On the first of their moonwalks, the astronauts of Apollos 12 and 14 set out the Apollo Lunar Surface Experiments Package, a nuclear-powered array of instruments including a seismometer to detect moonquakes, a magnetometer to hunt for any trace of a magnetic field, and other instruments to analyze solar wind gases and charged particles streaming past the Moon. Their second moonwalks were devoted to geologic exploration.

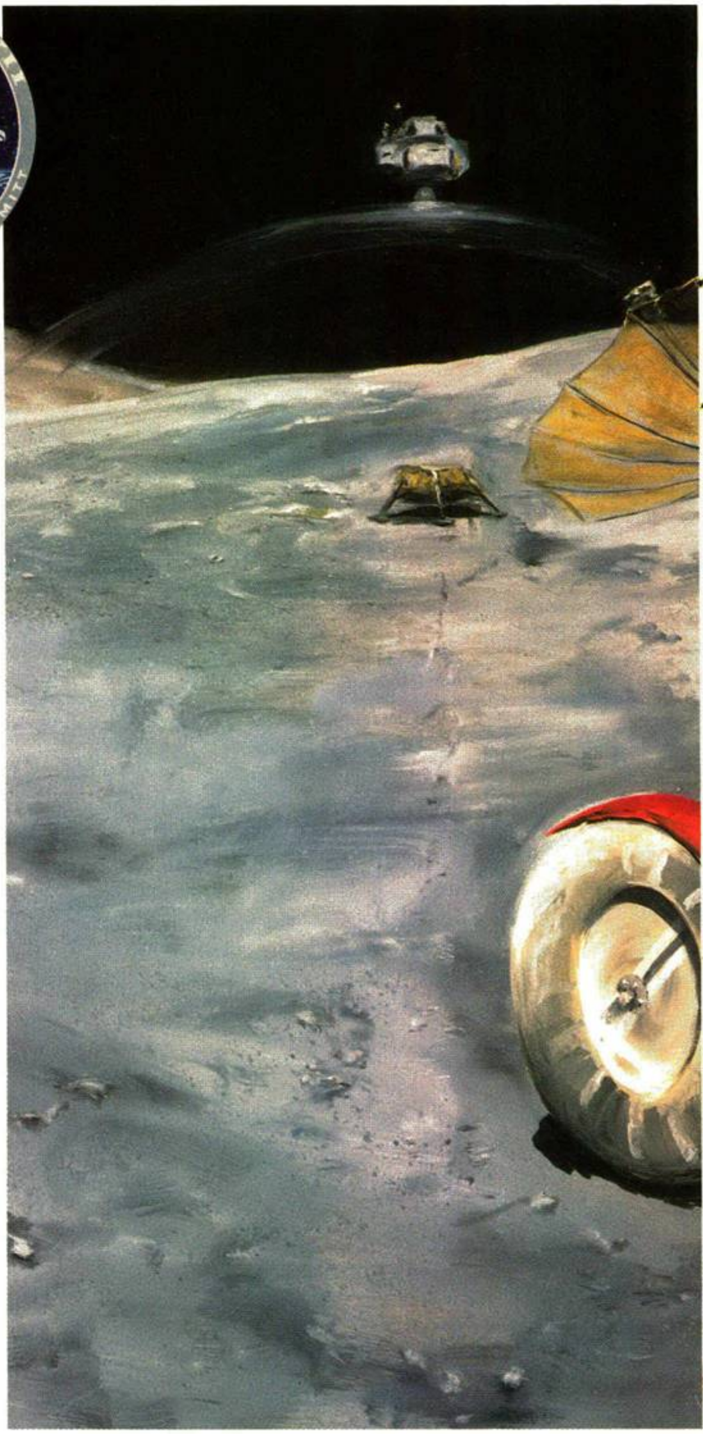
In their single moonwalk, Armstrong and Aldrin never strayed more than a couple of hundred feet from their lander; Conrad and Bean ventured more than six times as far as they prospected for samples on the lava plains of the Ocean of Storms. They ran from one crater to another in long, loping, slow-motion strides. Bean would later recall that each step launched him into the air for long seconds while he wondered whether he would land on a rock or in a pothole. He learned to anticipate each new step while still airborne, shifting his weight as he landed and immediately pushing off, setting up a rhythm, as if he were bounding across a rocky stream. If it was demanding, that only made it more fun. And the Moon afforded him a luxury unknown to any runner on Earth, a chance to relax in the midst of each step. It seemed, to Bean's amazement, that he would never get tired.

It's easy to imagine that as Conrad and Bean roamed the Ocean of Storms they were thrilled with their exploration. The reality was somewhat different. Like most of the Moon voyagers, they were test pilots, not explorers, and their mind was on their work. The overwhelming emotion they felt during the moonwalks — aside from the sheer joy of walking and running in lunar gravity — was the anxiety created by the mission's timeline, which was jammed with objectives. But every once in a while, they managed to steal a moment to take in the experience. During a long run to the Surveyor crater, Bean leaned back until he was looking into the black

"Here man completed his first exploration of the Moon, December 1972, A. D. May the spirit of peace in which we came be reflected in the lives of all mankind."

APOLLO XVII
CERNAN • EVANS • SCHMITT

NASA



dome of the lunar sky, until his eyes found Earth, a small and lovely jewel set in velvet. He said to himself, *This is the Moon. That is the Earth. I'm really here.*

Exploring

Even before Apollo, geologists suspected that the lunar surface records events from the earliest history of the solar system that have long been erased on Earth by water, wind, and geologic activity. For these scientists, the Moon was a 4.6-billion-year-old book waiting to be read. In February 1971, Apollo 14's Alan Shepard and Ed Mitchell visited the Fra Mauro highlands. Fra Mauro was like an airless, rock-strewn Sahara, with undulating ridges that reminded the men of sand dunes. The ridges were believed to be composed of material ejected from the giant Imbrium impact basin, 340 miles to the north. The rocks they brought back told scientists that the basin had formed some 3.85 billion years ago.

If the first three landings (Apollos 11, 12, and 14) demonstrated the astronauts' potential for scientific discovery, then the last three missions (Apollos 15, 16, and 17) literally and figuratively took Apollo to its greatest scientific heights. These latter missions featured upgraded lunar modules that allowed the astronauts to live for three full days on the surface, improved backpacks for moonwalks lasting as long as seven hours and, most important, a battery-powered car called the Lunar Rover. With the Rover, astronauts ranged for miles across the surface and visited some of the most spectacular places on the Moon. To prepare for these missions, the astronauts spent months studying with lunar scientists, training to be surrogate geologists in the quest for lunar treasure.

One moment that epitomized the excitement of the later missions came as Apollo 15's Dave Scott and Jim Irwin stood high on the slopes of a lunar mountain prospecting for samples. Suddenly they spotted a small white rock perched atop a pedestal of dust. When Scott held the sample in his gloved hand, both men realized what they had found: a chunk of anorthosite, the rock suspected to comprise the Moon's primordial crust. This sample, which the press dubbed the Genesis rock, dated back some 4.5 billion years, almost all the way to the Moon's birth.

On Apollo 16, John Young and Charlie Duke extended Apollo's reach with an expedition to the Moon's central highlands. Expecting to find ancient lava flows, Young and Duke instead found a landscape shaped by the violence of cosmic bombardment. Then, in December 1972, came the final landing, Apollo 17. Geologist-astronaut Harrison "Jack" Schmitt, with mission commander Gene Cernan, spent 75 hours in a spectacular steep-walled canyon at the rim of the Sea of Serenity. In three moonwalks lasting a total of 22 hours, they drove more than 19 miles and collected more than 240 pounds of samples. But even as Cernan and Schmitt showed just how much Apollo was capable of, it was over.

Looking back

Today, Pete Conrad is a vice president of McDonnell Douglas, where he has been a key player in the Delta Clipper project to develop a single-stage reusable launch vehicle. Conrad will tell you that he doesn't look at the Moon. If anything, he says, when someone says "space" he thinks about his 1973 mission to repair

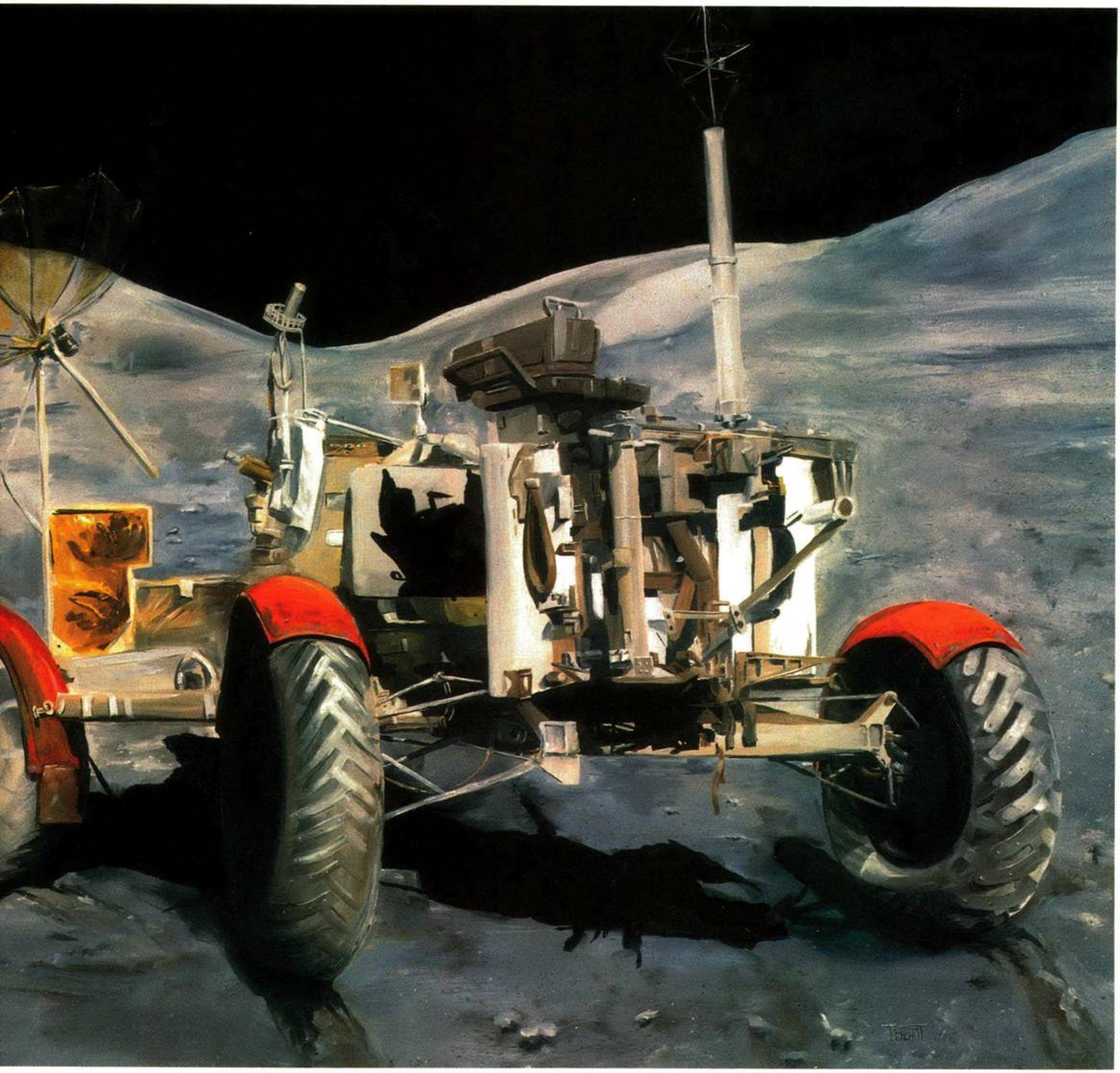


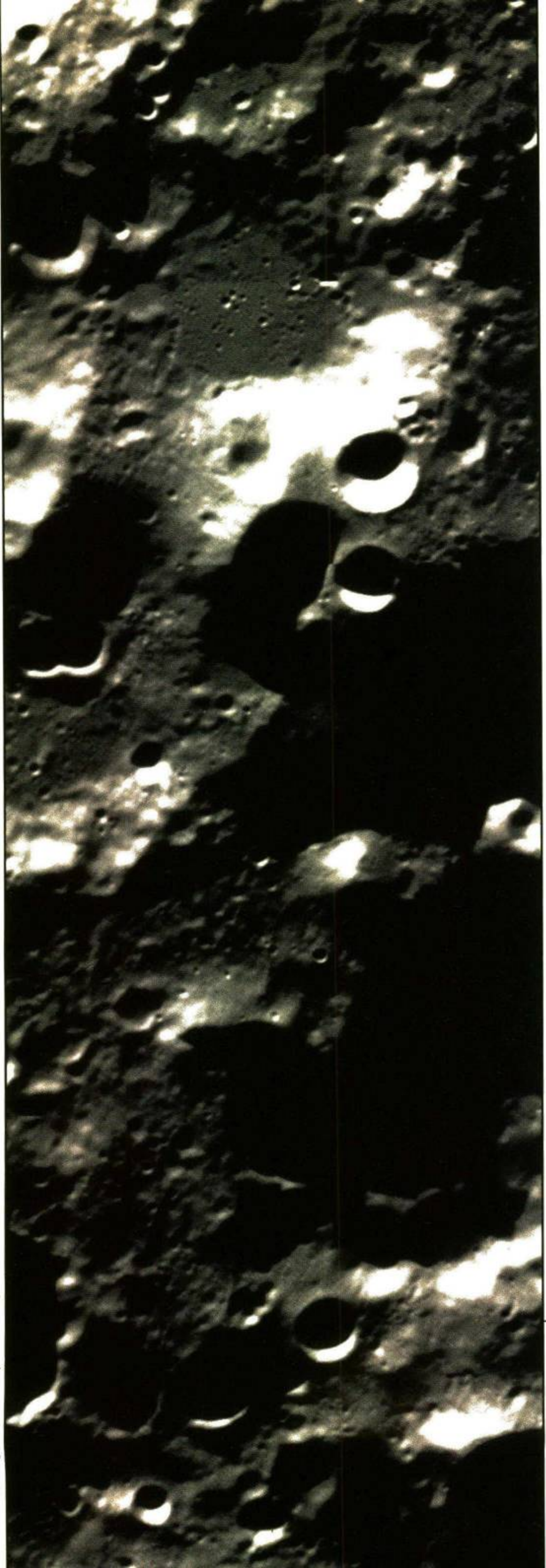
Illustration by Thomas L. Hunt

the Skylab space station in Earth orbit. His philosophy is simple: *Don't look back.* Not all the astronauts are quite so emphatic. Alan Shepard, for example, says he never looks at the Moon anymore without experiencing a moment of sheer amazement that he was there, before going back to whatever he was doing. And Bill Anders has never forgotten the sight of the first Earthrise, which he says changed his perspective forever.

For two of the moonwalkers, the experience of going to the Moon caused them to drastically change their lives: Ed Mitchell, who performed an ESP experiment on Apollo 14, left NASA to devote himself to the study of consciousness. Jim Irwin, who said that he felt the presence of God on the Moon, retired to become an evangelical minister. Before he died in 1991, Irwin spent the last two decades of his life sharing his faith around the world.

Today, for the Moon voyagers, Apollo is part of a distant past. But we can revisit their experiences in our imaginations. We can look for Tranquillity Base and the Ocean of Storms and Fra Mauro and the other places where men once walked. We can trace the paths the orbiting command modules made across the Moon's bright face. For us, the wonder of Apollo will always be available, anytime the Moon is out. ☐

Andrew Chaikin is a freelance writer living in Boston, Massachusetts. He is the author of the book A Man on the Moon *(Viking Press, 1994).*



Clementine MAPS THE MOON

Launched in January and reaching lunar orbit one month later, the Clementine spacecraft sent back detailed images of the Moon so scientists can accurately map its entire surface and mineralogy.

by David Bruning

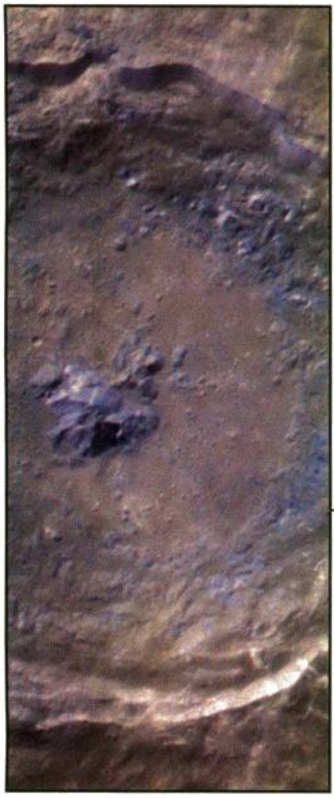
The first probe to escape Earth's gravity reached the Moon in 1959. Seventeen years later, space scientists sent their last mission dedicated to studying the Moon. Last mission until now, that is. Clementine, a space probe funded by the Department of Defense, reached lunar orbit earlier this year to spend two months mapping the Moon's surface in unprecedented detail.

Clementine's odyssey started on January 25, 1994, on top of an Air Force Titan IIG rocket. Launched from Vandenberg Air Force Base in California, the satellite orbited Earth for a little over a week while engineers checked out its systems. On February 3, flight controllers at the Naval Research Laboratory in Maryland gave the signal to light the rocket booster that would take Clementine out of Earth orbit. After two looping orbits that used Earth's gravity to boost the size of the orbit and change its direction, the spacecraft reached the Moon on February 19 and started business immediately.

Clementine's job was to map the surface of the Moon in great detail, both topographically and geologically, by taking images at several different wavelengths. ("Was" because by the

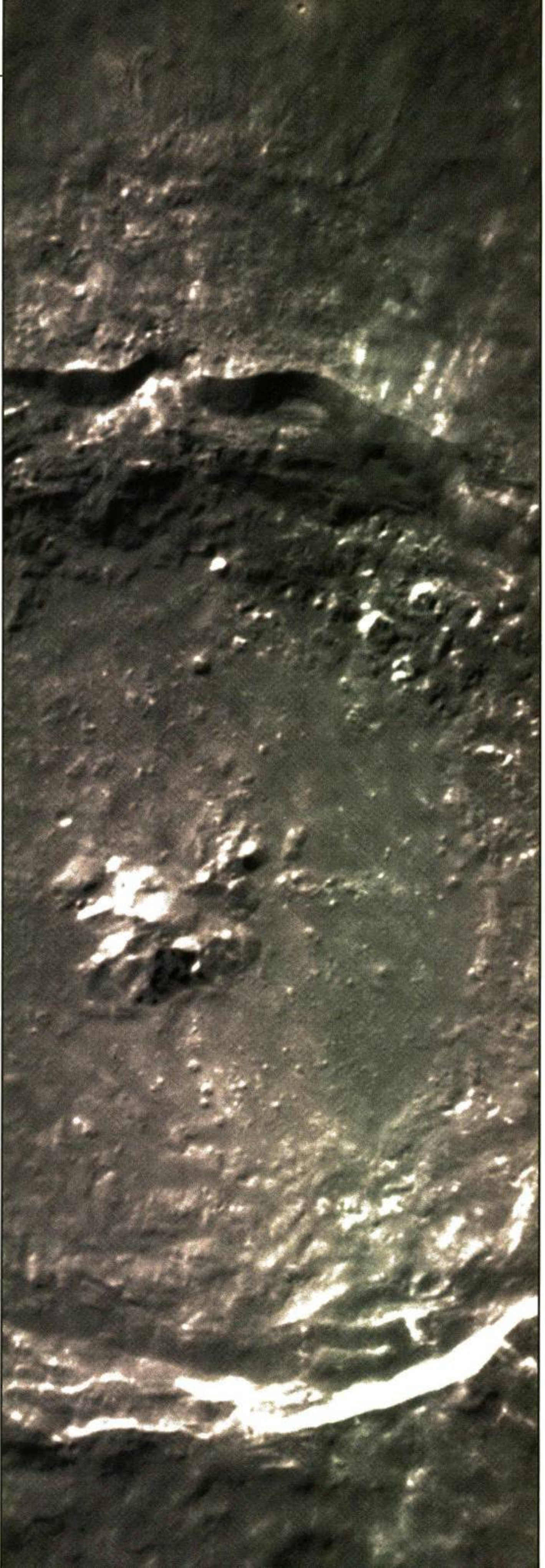
THESE ROCKY HIGHLANDS lie south of Clavius and near the Moon's south pole. The Sun is almost setting as viewed from this region so mountains and crater walls cast long shadows. The image scale varies among the four large images in this article due to the spacecraft's eccentric orbit. All fall along a swath located at 11° west longitude.

All images from NRL/Dept. of Defense, unless otherwise noted



THE YOUNG CRATER TYCHO (perhaps only 100 million years old) appears in the Moon's southern hemisphere and has a diameter of 85 kilometers.

TYCHO'S CENTRAL PEAK and parts of the crater floor appear more prominent in this image, which enhances blue light.

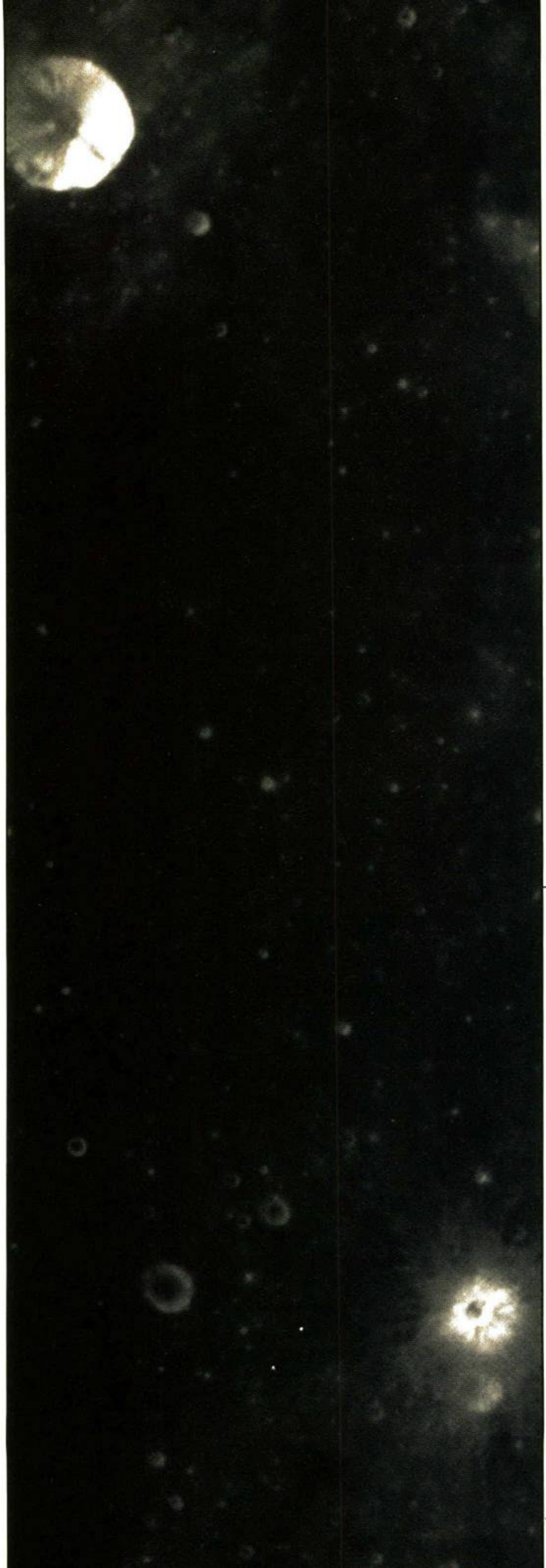


time you read this, the spacecraft should be on its way to an asteroid.) Although the areas considered for Apollo landings were mapped down to 1-meter resolution, astronomers surprisingly haven't mapped some areas at all and others at only 100- to 300-meter resolution. The equatorial orbits of most previous probes were not ideally suited to mapping the polar regions, for example.

Apollo's great success was that rocks collected by the astronauts provided much of our geological knowledge of the Moon. But the astronauts could collect a limited number of rocks from just six sites, and finds like the rare, old "Genesis" rock found by Apollo 15 were purely lucky events. The astronauts didn't have enough time on the surface to conduct systematic surveys or explore large regions of the Moon. So the geological findings from Apollo are incomplete and form just a preliminary look at our satellite.

But Clementine will change that. ("Will" because scientists won't have time to study the images until after the spacecraft moves on to the next encounter.) Its pole-to-pole orbit enabled the spacecraft to fly over every region of the Moon and map each area equally well. Furthermore, the spacecraft remained in orbit for about 70 days, providing more than one look at each region. During each five-hour orbit, Clementine recorded more than 4,000 images — that's more than a million images over the two-month mission.

Unlike previous missions that imaged primarily in black and white, Clementine used a battery of instruments to image at several wave-

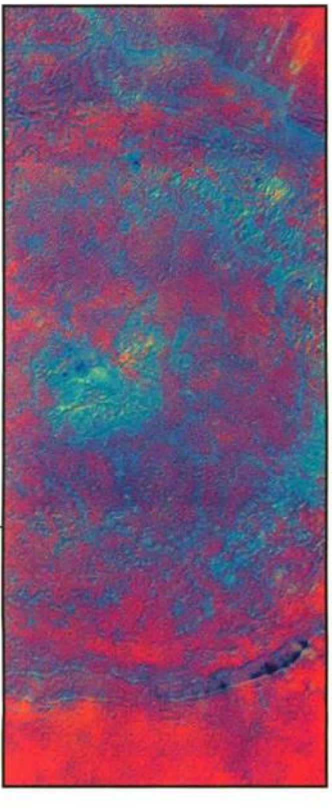


lengths — the UV/VIS camera in the ultraviolet and visible parts of the spectrum, the NIR camera in the near infrared, and the LWIR camera at long wavelengths in the infrared. The multi-wavelength images revealed what types of rocks lie in each region of the lunar surface, not just the few Apollo sites. These imagers are joined by a high-resolution camera (HIRES) that captured lunar details down to 10 meters across. This camera also forms part of the light imaging detection and ranging system (LIDAR) that determined altitudes of lunar features to within about 40 m over the Moon's midlatitudes (60° north to 60° south).

What makes this spacecraft remarkable is that it follows the faster, lighter, cheaper mode that NASA currently espouses. It weighs only 500 pounds, cost just $55 million to build (and another $20 million to launch), and went from idea to launch in a mere 22 months. Ironically, NASA didn't build this spacecraft: The Ballistic Missile Defense Organization funded it and a team of about 55 people at the Naval Research Laboratory designed and built it. The Lawrence Livermore National Laboratory in Livermore, California, built the lightweight imagers.

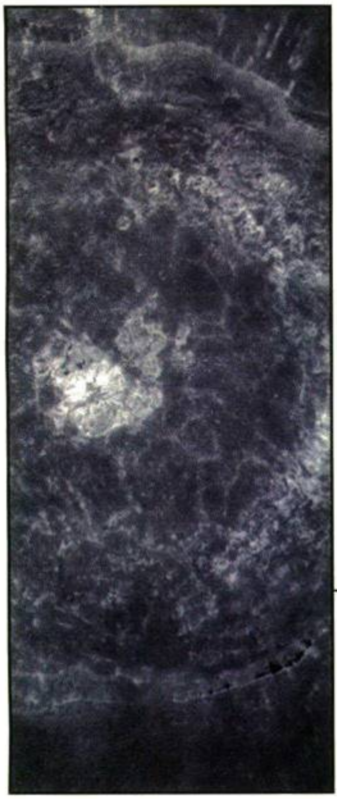
In addition to the special cameras, Clementine has some novel components, such as the largest data recorder (1.6 gigabyte capacity) ever flown. It also has a super-fast computer to process images and new lightweight solar cells that pump out more energy per square foot than previous cells. And a new nickel-hydrogen battery has already proved its mettle.

THE CRATER KUNDT (top left) and the small 2-km-wide Lassell H (bottom right) lie in the dark, flat lava plains of Mare Nubium.

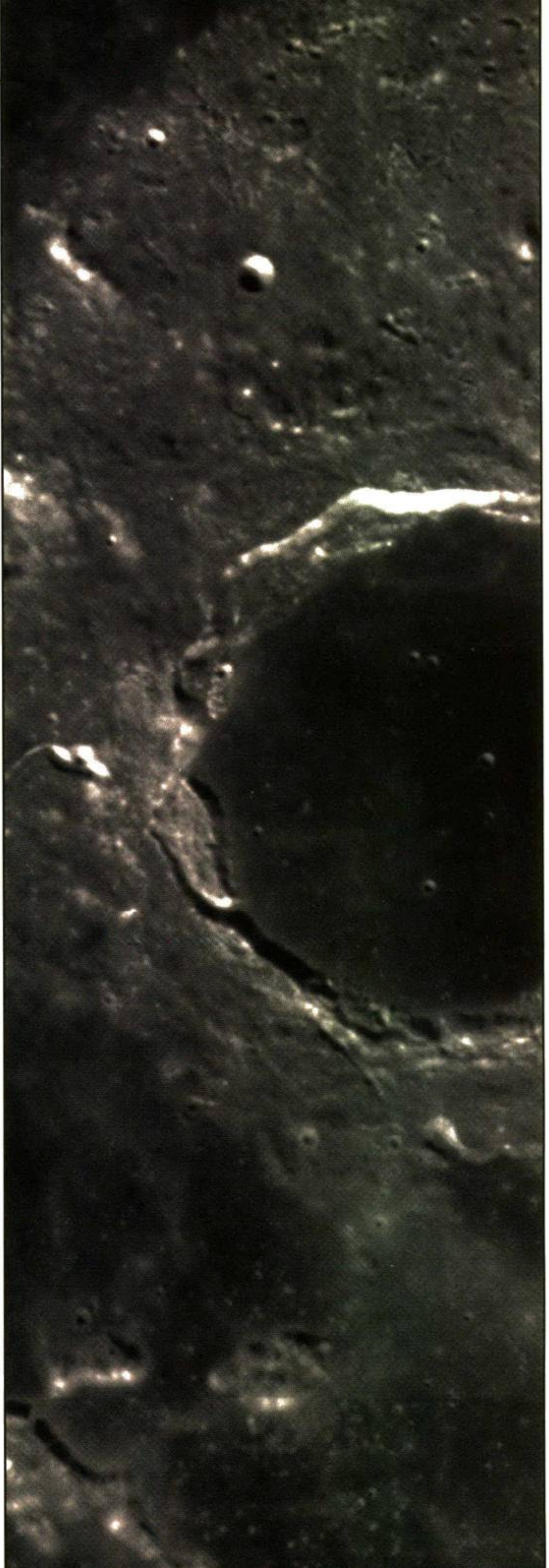


TYCHO'S ROCK TYPES show up plainly in this false-color picture made from images taken at several wavelengths.

Image processing by Brian Fessler, Lunar and Planetary Institute



TYCHO'S FLOOR shows either cracks from cooling or ancient evidence of rising and sinking material.

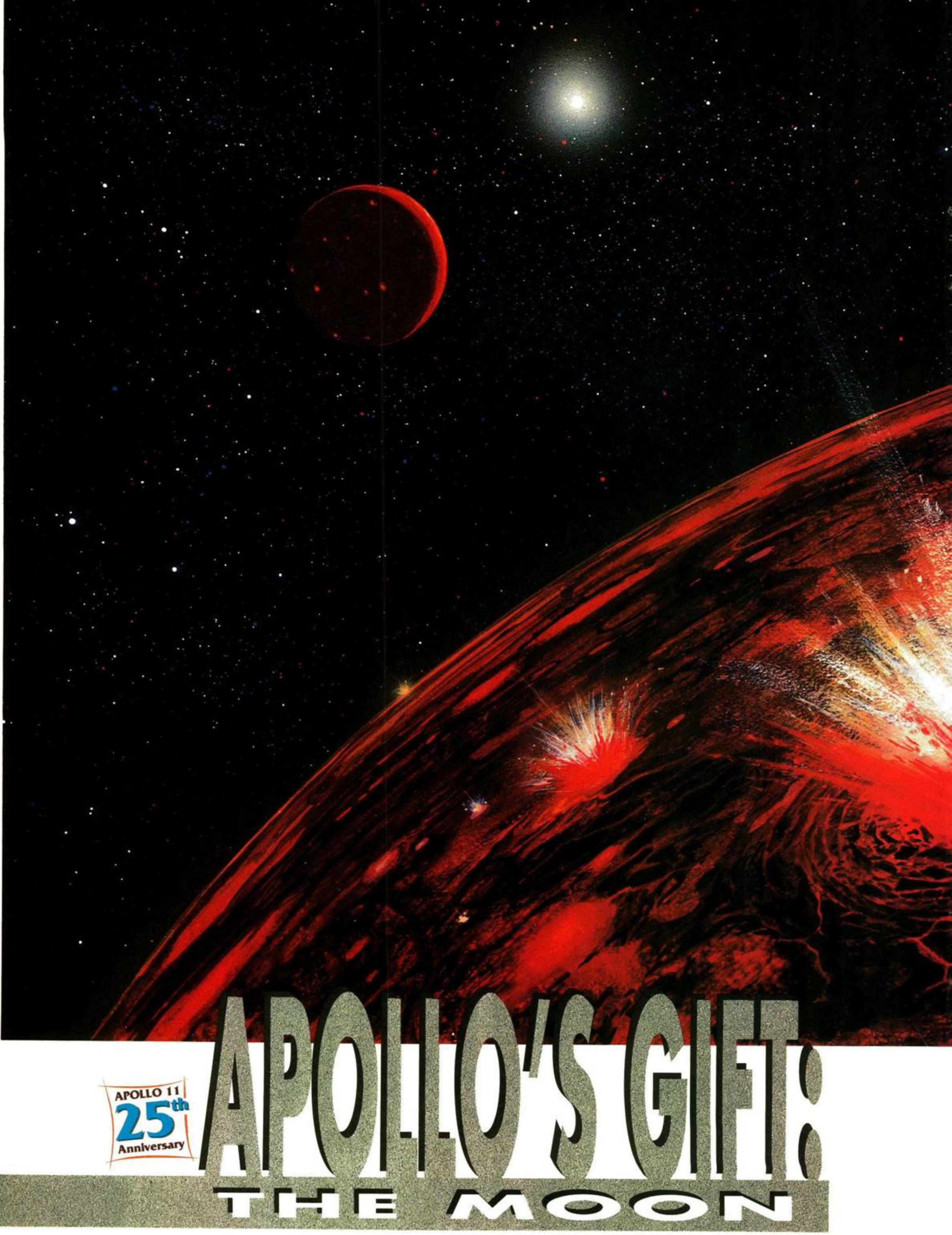


PLATO STRETCHES across more than 100 kilometers near Mare Frigoris (top) and the Moon's north pole.

When it accidentally discharged while in Earth orbit, spacecraft controllers were able to recharge it to its full capacity. If it had been a rechargeable nickel-cadmium (Ni-Cad) battery, they wouldn't have been able to recharge it and might have had to scrap the mission.

The special capabilities of Clementine will enable planetary scientists to decipher how volcanism, impacts, and large-scale motions of the crust (called tectonics) shaped the Moon's surface. But the spacecraft's mission doesn't stop there. At press time, mission controllers planned to boost the satellite out of lunar orbit in late May. Clementine was to return to Earth orbit for about three weeks before being sent past the Moon one last time for a gravity-assisted boost to an encounter with asteroid 1620 Geographos. This will mark the first fly-by of a near-Earth asteroid.

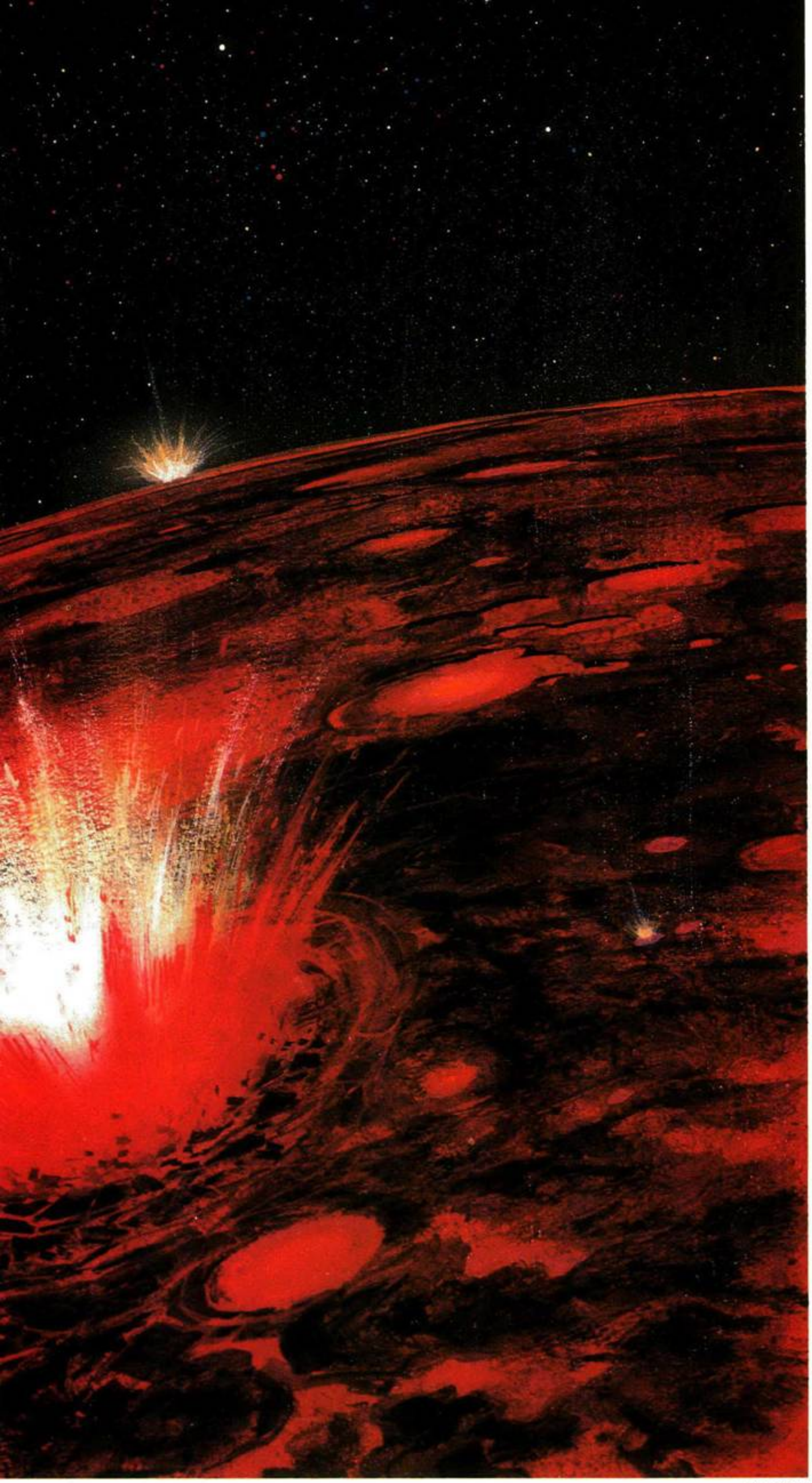
The spacecraft should reach the asteroid in late August after traveling about 8 million km. Whizzing by at 11 km/sec, it will pass within 100 km of Geographos, revealing details as small as 5 m across. (For more information about the asteroid flyby, see "The Moon-Miner's Daughter," February 1994.) That's still not the end of Clementine's mission. It may go on to take a look at asteroid 1983 RD in October 1995. The gold miner's daughter, Clementine, was "last and gone forever" causing "dreadful sorrow" to the singer. But spacecraft Clementine will cause no sorrow when its mission ends, because scientist have a chance to glean from its data a wealth of geological riches about the Moon and possibly two asteroids. □



APOLLO 11
25th
Anniversary

APOLLO'S GIFT:

THE MOON



Ron Miller

Twenty-five years ago this summer, planetary scientists first put their hands on a piece of the Moon. In its rocks they have read the history of an alien world and glimpsed our own planet's earliest days.

by Graham Ryder

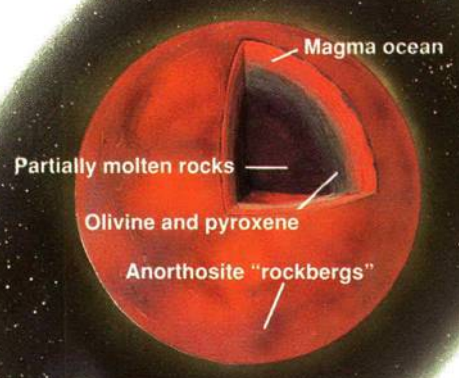
Your naked eye alone is enough to tell a most important fact about the Moon: Its patches of light and dark gray show that it isn't a homogeneous, bland place. The study of those patches began almost four centuries ago when Galileo first pointed his spyglass at the Moon, and it continues today with images from the Clementine spacecraft (see page 36). The years in between have brought a few meteorites from the Moon, many remote-sensing studies by spacecraft and from Earth — and 382 kilograms (84.2 lbs.) of rocks and soil collected during the Apollo missions.

Apollo destroyed forever the idea that the Moon was a primitive, unaltered body. Before Apollo, some scientists proposed that the Moon was an inert, unevolved object much like a gigantic chondrite meteorite. But the samples brought back by the astronauts showed that the Moon melted during its catastropic birth over 4.5 billion years ago and that it remained volcanically active for at least 2 billion years after. In short, the Moon that solar system scientists know today is a fascinating and far more complex little planet than anyone envisioned before the Moon landings.

With this change of view, more than just the Moon's history is at stake. Understanding the evolution of rocky bodies from Mercury out to at least the asteroid belt depends in part on getting things right about the Moon. After a body forms, its history is governed mainly by heat — heat production, heat retention, heat movement, and heat escape. Fortunately, in a rocky planet this history leaves tracks, which scientists now know better for the Moon than for any planet except Earth itself.

The diagrams that follow show the evolution of the Moon as scientists understand it. A series of cross-sections of the Moon's upper few hundred kilometers (about half its volume) depict in a simplified form what was happening at successive times. The dates do not fall evenly spaced throughout the life of the Moon because most of the significant turning points took place early in lunar history, and very little has happened over the last 2 billion years.

4.5 TO 4.4 BILLION YEARS AGO



A Moon Wrapped in Lava

4.5 to 4.4 billion years ago

The Moon was born in fire and out of the Earth, but not from the Pacific Ocean, as some scientists once pictured it. Instead, a planetary body about the size of Mars struck the infant Earth with a glancing blow when it had nearly reached its present size. In something like 15 minutes, this titanic collision squirted a jet of molten and vaporized rock from Earth's newly formed crust and the impactor. Much of the jet escaped into the emptiness of the solar system or fell back onto the Earth. The residue, however, went into orbit, where the fragments fell together to make the Moon. (See "Piecing Together Earth's Early History," June 1989.)

The tremendous heat from the rapid accretion of the Moon probably started it melting well before it had fully formed. The evidence of some primitive material from great depths suggests that the Moon did not melt right through, but its outer layers at least were covered with a deep, Moon-wide "ocean" of magma — molten rock.

As the magma ocean covered the Moon, the lunar crust, 60 to 120 km thick, began to form. It has a much lower density than the lunar interior and its composition also differs markedly. Whereas the Moon as a whole does not have more than about 3 or 4 percent alumina (aluminum oxide), the crust has about 25 percent. Clearly some process extracted most of the alumina from the interior and dumped it into the crust, chiefly as the mineral plagioclase feldspar. Igneous rocks mainly made out of this mineral are called anorthosites and are common in the light-colored lunar highlands.

Where did the highlands come from? As any telescope shows, the lunar highlands are heavily cratered. Anorthosite samples that survived this pummeling are coarsely grained, slowly cooled rocks like those that crystallize at depth within large bodies of magma. Radioisotope measurements suggest that they are more than 4.45 billion years old. To produce such a crust implies a global ocean of liquid rock at least several hundred kilometers deep. In this ocean, light feldspar crystals drifted upward and accumulated into floating "rockbergs" of anorthosite, while convection churned the magma like a boiling pot. The minerals olivine and pyroxene, rich in magnesium and iron, started to crystallize even before the feldspar did, but they are denser and sank to form a *mantle.*

As the olivines and pyroxenes sank, so perhaps did fragments of the magma ocean chilled by exposure to space at the surface of the lava ocean. A continuing rain of impacts would have broken up both the chilled crust and the anorthosite rockbergs, contributing to a chaotic mix.

Toughening Up

about 4.4 billion years ago

As it slowly cooled, the magma ocean formed a thickening crustal skin. Crystallization continued to feed anorthosite rocks into the crust and olivine- and pyroxene-rich materials to the mantle. But because of convection and local variations in the magmas, the crust was not uniform all over the Moon. Indeed, the crust appears rather thicker on the farside of the Moon than on the near. While this is probably a product of the original magma ocean, scientists don't yet have a commonly accepted explanation for the difference.

Various minerals left the magma to become crystals as it cooled past their melting points. This changed the remaining magma's composition and diminished its amount. Eventually only a small residue of magma rich in iron and titanium remained, lying perhaps just under the lightweight crust.

Finally, only a few elements that don't easily fit into common mineral structures during crystallization remained in what was left of the magma ocean. This residual magma was greatly enriched with incompatible elements, including potassium (K), the rare-earth elements (REE), and phosphorus (P). This residue, given the acronym KREEP, turns up as a component in the younger lunar breccias — rocks made of fragments welded by impacts. Although formed well below the surface, KREEP found its way into the anorthosite upper crust during later melting and after impacts deeply disrupted the lunar surface.

Seen from the outside in this period, the whole lunar surface must have looked like the highlands do today — heavily cratered by impacts. But lacking a deep magma ocean, broken pieces of crust did not sink out of sight as they had formerly, but remained as brecciated blocks.

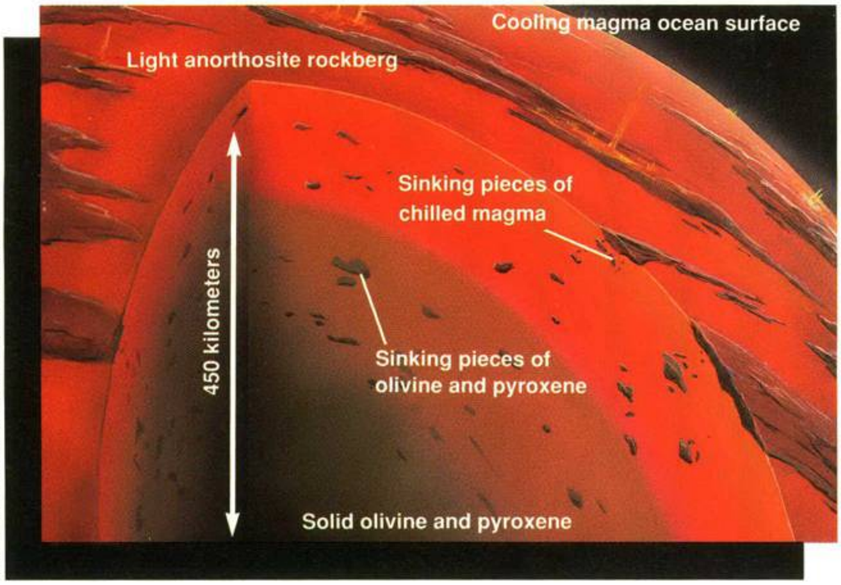
Inside Out

4.4 to 4.3 billion years ago

The Moon continued to cool. But when the dregs of the magma ocean crystallized, the Moon was left in a precarious state. Its interior was still quite hot, with a temperature of more than 1,300 kelvins. Moreover, very dense minerals lay on top of far lighter and hotter ones — a perfect recipe for instability. Finally, the inevitable happened and the pile overturned. Like rush-hour crowds jostling through each other at a subway entrance, pieces of dense material from the crust sank and lighter ones rose from the mantle to replace them.

When solid material from the magnesium-rich mantle thrust upward, it felt a decrease in pressure, causing

4.5 TO 4.4 BILLION YEARS AGO



Cooling magma ocean surface
Light anorthosite rockberg
Sinking pieces of chilled magma
450 kilometers
Sinking pieces of olivine and pyroxene
Solid olivine and pyroxene

ASTRONOMY: all cutaway diagrams by Lee Vande Visse

the material to liquify again. This produced even lower-density magnesium magmas that rose higher still, all the way up into the crust. At least some of these magmas turned basaltic (if they were not already) by contamination with the olivine and pyroxene residue of the older magma ocean, some of which was on its way down. Some magmas appear to have melted and absorbed pieces of the old anorthositic crust as well.

Crystallization in the cooler crust produced rocks similar to those we find on Earth in intrusions of basaltic magma. These consist of coarse-grained rocks of olivine and plagioclase (dunites and troctolites) and rocks of pyroxene and plagioclase (norites and gabbros). Fragments of this type of rock have been found in the Apollo sample collections and provide the best clues to what probably happened on the Moon. Their chemistry shows there's no doubt that these rocks formed from magmas that were chemically distinct from those that produced the original anorthosites and younger ones as well.

Making the Lunar Fruitcake
about 4.3 to 3.9 billion years ago

The turnover lasted roughly 500 million years in all. While this was short in lunar terms, it is a span of time as long as that separating us from the first obvious fossils on Earth. During those 500 million years the mantle of the Moon remained hot enough to continue sending up fingers of lightweight basaltic magma into the crust. There they crystallized as bodies of rock distinct from the crust around them. Although the main overturn appears to have been complete 4.3 billion years ago, the process continued for a long time, since it was not very efficient or regular, and the mantle of the Moon differed noticeably from place to place.

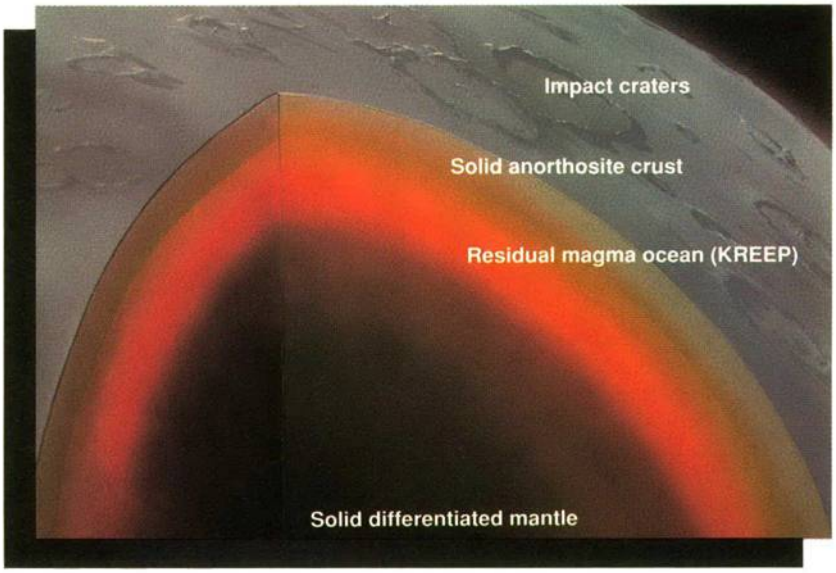
The incompatible KREEP elements in the residue of the initial magma ocean included most of the elements that produce heat by radioactive decay, in particular potassium, uranium, and thorium. Therefore the residue and the magmas it contaminated were particularly prone to remelting. As these remelts rose and then crystallized in the crust, some formed small lumps of lunar granite, rocks very rich in potassium and incompatible elements. A lunar "fruitcake" was taking shape.

Yet not everything remained buried within the crust. Some lavas rich in KREEP components erupted onto the surface (although only rarely have fragments been found from this era). From some of the deeper mantle material, now enriched in iron and titanium as the heavy magma sank, melts of iron-rich basalt began to form and work their way to the surface, where they pooled into maria like those we see today. Some rocks produced in impacts during this period have been found among the Apollo samples. But strangely, few if any impact-melt rocks date from this time, and it is not clear whether the impact rate was as high then as it was a little later.

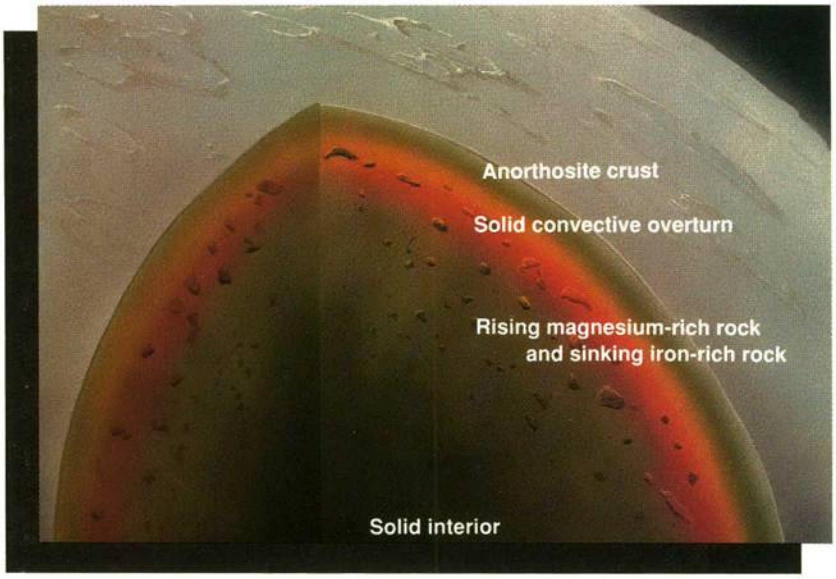
The Late Great Impact Basins
3.9 to 3.8 billion years ago

By 3.9 billion years ago, the next-to-last act had arrived in the lunar drama. On Earth, single-celled life

4.4 BILLION YEARS AGO



4.4 TO 4.3 BILLION YEARS AGO


Anorthosite crust
Solid convective overturn
Rising magnesium-rich rock and sinking iron-rich rock
Solid interior

had only just emerged and begun its long journey toward today. If we were transported back in time to then, we'd find our own planet uninhabitable, its air unbreathable. But on the Moon, the geological story was nearly over; both internal and external activity were winding to a close.

During this period many of the great multiringed basins such as Nectaris (3.92 billion years old) Serenitatis (3.87 billion), and Imbrium (3.85 billion) were formed, as well as numerous smaller craters. It is debatable whether the intensity of impacts during this period was merely the tail end of a fairly continuous bombardment over the previous 600 million years or something quite new and different. (If the former is true, then it's puzzling that impact-melt rocks older than about 3.9 billion years are sparse or even absent.) The giant basins we see today may have had similar (or even larger) ancestors which were destroyed many times over — or they may be features that have appeared only relatively late in lunar history.

In any case, giant basin-making impacts had profound effects on the topography and geology of large regions of the Moon. Such impacts dug into the crust and shattered it, producing vast sheets of impact-melted rock and blanketing the regions around them with fragmented material. Ejecta contain excavated material from deep in the crust at the site and allow scientists to study it.

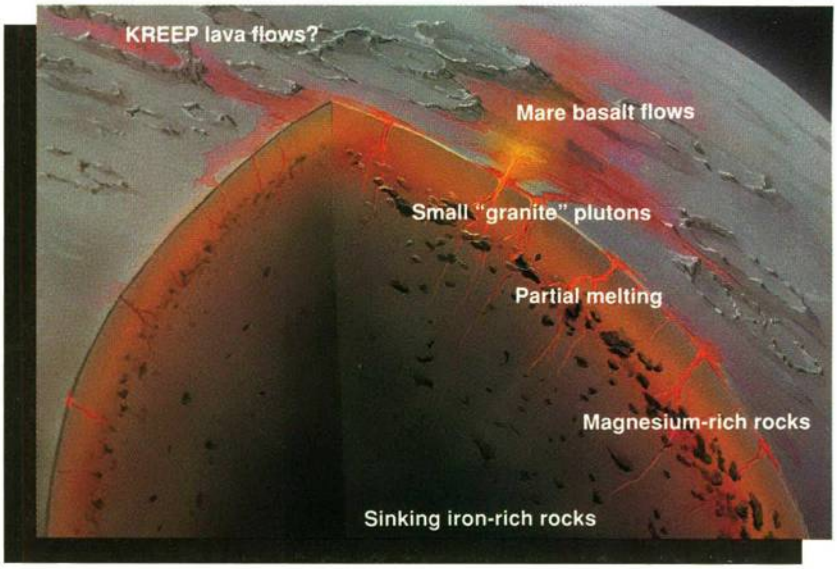
Impact-melted rocks are valuable in another way. These are mixtures of melted target rocks and contamination from the impacting body, so they provide an average composition for some part of the crust. Also, because they contain radioisotopes, the melted rocks allow scientists to date a particular impact event. The main problem comes in identifying the source! Only for the Serenitatis basin has a particular melt type been linked fairly positively to a particular basin. In another case, the eruption of a volcanic KREEP basalt in the Imbrium basin immediately after the impact appears related in some way to the impact. Elsewhere in this period, volcanism from melting of the deeper mantle took place unrelated to any impacts and quite a variety of these mare basalts have been identified. It's also likely that some rock masses crept up into the crust at this time, but they remain largely unexcavated and have not been identified.

Today's Moon Emerges

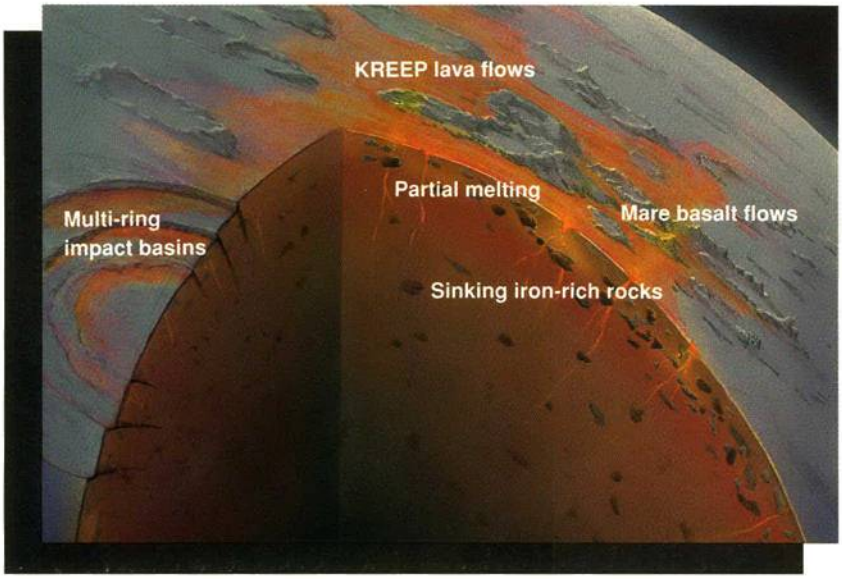
3.8 to 2.0 billion years ago

With the end of the basin-making impacts, the Moon began to take on its present appearance. The dark lava plains, or maria, so prominent on the Moon's face all erupted astonishingly long ago. We see them today only because the impact rate declined sharply after the Orientale basin formed about 3.0 billion years ago. This meant that lava flows were largely preserved, not destroyed as they were earlier. These mare basalt lavas are very iron-rich as compared with typical basalts on Earth. Some are so rich in titanium they might make good sources of ore.

4.3 TO 3.9 BILLION YEARS AGO



3.9 TO 3.8 BILLION YEARS AGO



Flowing rapidly with about the consistency of motor oil, the lavas poured out of vents and ran for hundreds of kilometers before finally hardening. They pooled in low-lying areas, including impact basins, and are everywhere much younger than the basins they fill.

Other mare magmas erupted in sprays and fire fountains after rapidly ascending from several hundred kilometers' depth. Shooting into the lunar sky, they formed droplets that usually solidified as glass spheres, piling up near their source vents and blanketing the local terrain. One example is the famous orange glass discovered by the Apollo 17 astronauts. Some volcanic glasses have components that apparently were not involved in the original melting of the Moon; they suggest that at least some of the Moon's deepest interior was not molten at its birth.

The mare basalts are an extremely varied set; each is virtually unique. The source of each type scientists have investigated so far differs in some way from that of the others. Indeed, high-titanium mare basalts, for example, came from sources substantially different from those that produced low-titanium basalts. Laboratory experiments show that the mare basalts originated in the high temperatures and pressures found at depths ranging from about 100 km to as much as 400 km.

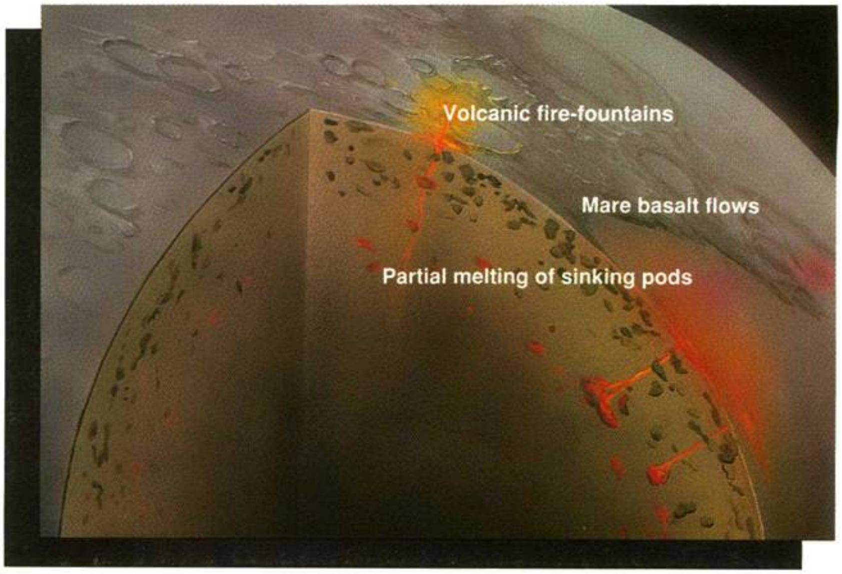
The chemistry of the mare basalts also shows that the mantle sources that produced them had lost their plagioclase feldspar components some time before about 4.35 billion years ago. These "lost" components are the very same ones that now form the dominant anorthositic rocks of the crust. Likewise, the mantle sources of mare basalts are the same olivines and pyroxenes that crystallized in the deep magma ocean at the start. Thus the lunar crust and mantle come together like two irregular puzzle pieces that mate neatly.

Sometime about 2 billion years ago, lunar evolution came to an end. The Moon had cooled so much that its upper crust completely solidified; lava could no longer (or only rarely) break through and erupt. Since then, the Moon has been pockmarked by a rain of debris. This ranges from high-speed particles from the Sun and tiny dust particles all the way up to the large chunks of material that blasted out craters such as Copernicus (800 million years old) and Tycho (109 million). For all purposes, then, the Moon is dead and simply records external events passively.

But if the Moon's history is now basically over, the lunar world remains a magnificent museum for planetary scientists. It offers visitors from Earth a detailed glimpse of a time in the solar system's history which has all but vanished from our own planet's geological record. And as the first alien world humans have struggled to understand, it is the pathway to all the other worlds around us. □

Graham Ryder is a geologist and planetary scientist at Houston's Lunar and Planetary Institute, where his research specialty is lunar petrology.

3.8 TO 2.0 BILLION YEARS AGO



SKY ALMANAC

July 1994

Comet Shoemaker-Levy 9 Hits Jupiter

During a week-long period beginning on July 16, the fragmented comet Shoemaker-Levy 9 will fall into Jupiter's atmosphere and explode on the night side of the planet's limb. Observers won't see the impact sites until minutes after the strikes, when the planet's rotation brings the disturbed area into view. No one knows exactly what will be visible, but backyard astronomers with large telescopes and steady seeing may spot variations in the planet's cloud patterns.

Uranus and Neptune at Opposition

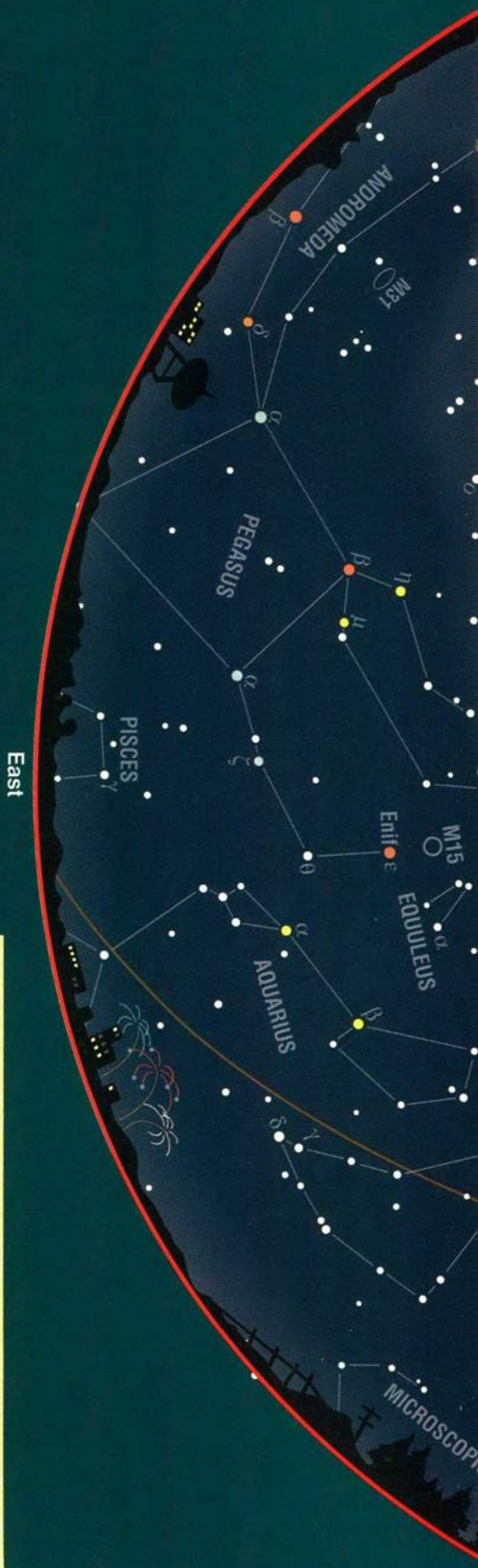
The distant gas giant planets Uranus and Neptune reach opposition on July 14 (Neptune) and 17 (Uranus). As such, they are placed ideally for observing. Uranus is barely visible with the naked eye on a dark night; Neptune can be spotted with binoculars. For best results, use a small telescope at moderate power to see the tiny bluish green disks of these faraway worlds.

Comet Tempel 1 Traverses Libra

Glowing at magnitude 9, Comet Tempel 1 this month appears as a fuzzy "star" sliding southeastward through the constellation Libra. A good pair of binoculars or a small telescope reveals the comet's fuzzy coma and differentiates it from the surrounding stars.

Mercury's Morning Apparition

During the middle of July Mercury pops up into the early morning sky, putting on a show for the remainder of the month. The orange-colored planet rises higher than normal above the horizon because of the steep angle the ecliptic makes during the month. Take out a pair of binoculars to spot Mercury, and after finding the planet see if it is visible with the eye alone.



CALENDAR OF EVENTS

3 The Moon is at apogee (251,453 miles from Earth), 1 a.m. EDT

5 The Moon passes 0.3° south of Mars, 1 a.m. EDT
Earth is at aphelion (94.5 million miles from the Sun), 3 p.m. EDT

7 The Moon passes 1.3° north of Mercury, 9 a.m. EDT

8 New Moon is at 5:37 p.m. EDT

12 The Moon passes 7° south of Venus, 8 a.m. EDT

14 Neptune is at opposition, noon EDT

15 First Quarter Moon is at 9:12 p.m. EDT

16 First Comet SL-9 fragment (A) strikes Jupiter, 3:26 p.m. EDT
The Moon passes 3° south of Jupiter, 7 p.m. EDT

17 Uranus is at opposition, midnight EDT
Mercury is at greatest western elongation (21°), 10 a.m. EDT

18 The Moon is at perigee (228,580 miles from Earth), 2 p.m. EDT

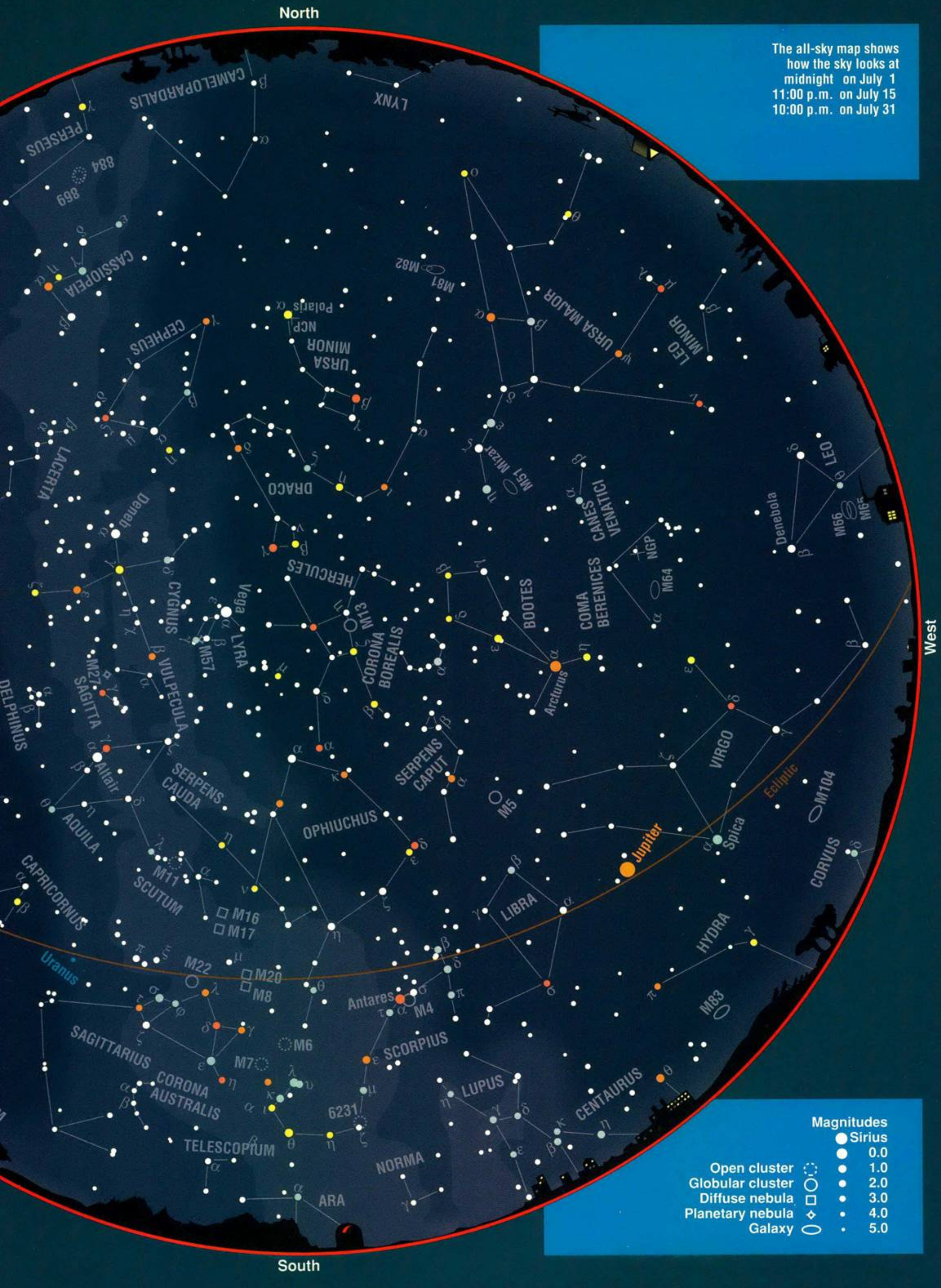
20 Brightest Comet SL-9 fragment (Q) strikes Jupiter, 3:12 p.m. EDT

22 Final Comet S-L 9 fragment (W) strikes Jupiter, 3:40 a.m. EDT
Full Moon is at 4:16 p.m. EDT

28 Southern Delta Aquarid meteor shower peaks, 7 p.m. EDT

30 Last Quarter Moon is at 8:40 a.m. EDT
The Moon is at apogee (251,087 miles from Earth), 7 p.m. EDT

The all-sky map shows how the sky looks at
midnight on July 1
11:00 p.m. on July 15
10:00 p.m. on July 31


North
South
West
CAMELOPARDALIS
LYNX
PERSEUS
884
869
CASSIOPEIA
CEPHEUS
Polaris
NCP
URSA MINOR
M81
M82
URSA MAJOR
LEO MINOR
LACERTA
DRACO
Mizar
M51
CANES VENATICI
LEO
Denebola
M66
M65
Deneb
CYGNUS
HERCULES
Vega
LYRA
M57
M13
CORONA BOREALIS
BOOTES
COMA BERENICES
NGP
M64
Arcturus
M27
SAGITTA
VULPECULA
DELPHINUS
Altair
SERPENS CAUDA
SERPENS CAPUT
OPHIUCHUS
M5
VIRGO
Ecliptic
M104
AQUILA
Jupiter
Spica
CORVUS
CAPRICORNUS
M11
SCUTUM
LIBRA
M16
M17
HYDRA
Uranus
M22
M20
M8
Antares
M4
M83
SAGITTARIUS
M6
SCORPIUS
M7
CORONA AUSTRALIS
LUPUS
CENTAURUS
6231
TELESCOPIUM
NORMA
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

SKY ALMANAC

by Deborah Byrd and Jeff Kanipe

Many pairs of earthly eyes will gaze toward the solar system's largest planet, Jupiter, this month, as the fragments of Comet Shoemaker-Levy 9 race toward their collision with it. Predictions abound, but no one really knows what Earthlings will see when the impacts take place over a period of seven days beginning on July 16.

Jupiter's location in the sky and its overall appearance are entirely predictable, however. As evening begins this month the planet appears as a bold light in the southwest in the constellation Virgo, not far from Spica, Virgo's brightest star.

Jupiter's opposition came in late April. That was when we passed between this planet and the Sun, and Jupiter was closest and brightest for the year. Now it has faded slightly in brightness, but still outshines all stars at magnitude –2.2. You can't miss it in the evening sky. Look for Jupiter on the evening of July 16, a few hours after the first comet crash, when the First Quarter Moon lies nearby. (See the box on the opposite page for complete information on viewing the demise of Comet Shoemaker-Levy 9.)

While gazing at Jupiter, you'll also notice another planet nearby. The brightest planet, Venus, shines in the west after sunset. It is so brilliant at magnitude –4.1 that you couldn't overlook it if you tried.

When the month begins, Venus can be found in the same tract of sky as Regulus, the heart of the Lion in the constellation Leo. Regulus is part of an asterism, or recognizable pattern of stars, called the Sickle. The Sickle appears poised to slice Venus in half in early July, but as these stars descend behind the planet in the western twilight sky this month, the blade of the Sickle misses the planet. Instead, Venus passes through the handle of the Sickle, sweeping only 1° north of Regulus — at the bottom of the handle — on July 10. A striking alignment of Venus, Regulus, and the Moon occurs on July 11, so grab your binoculars to view the alignment or consider photographing it with your camera and tripod.

Two planets — thought to be "twins" until the Voyager spacecraft passed near enough to reveal their differences — come to opposition within a few days of each other this month. Neptune reaches opposition on July 14, and Uranus on July 17. Both planets are in the constellation Sagittarius, placing them in the early morning sky. Neptune shines at magnitude 7.9. Even now, while brightest for the year, it requires optical aid to be seen.

Uranus, on the other hand, is just visible to the naked eye at magnitude 5.6. You can see this planet on a moonless night, under a very dark sky, using the chart on page 51 to locate its precise position. The disk of Uranus is a tiny 3.8" across. Look for its steady, bluish-green light. (Binoculars make its color more apparent.)

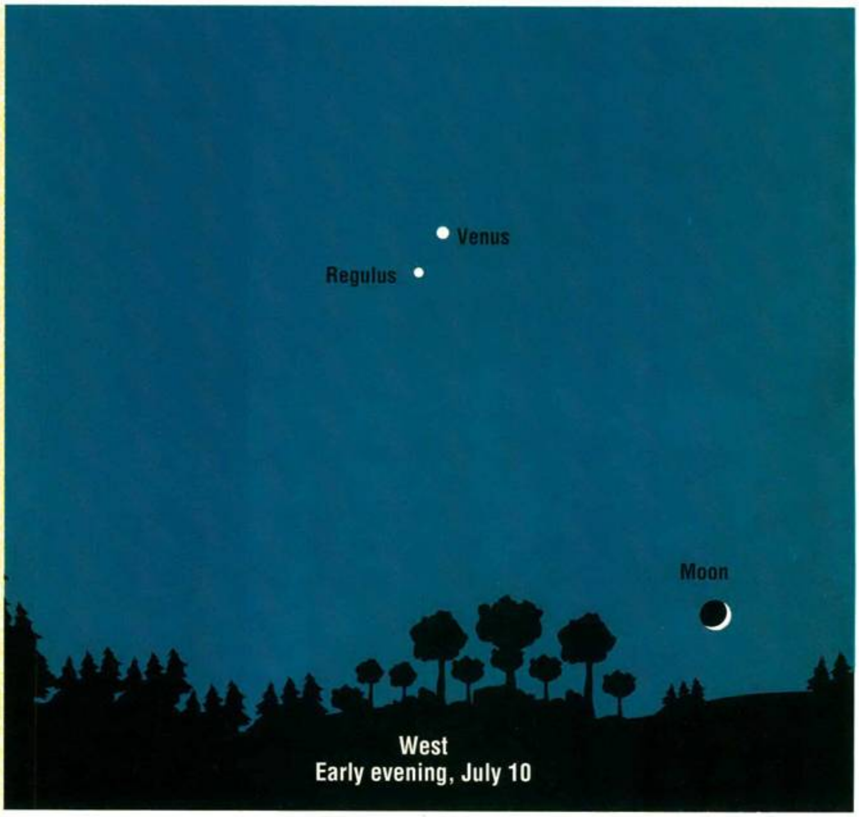
This month, the stars we traditionally think of as belonging to the evening sky in winter return to the east before dawn. The most elusive planet, Mercury, appears among them. It can be seen during the last three weeks of July. Its greatest western elongation, or greatest apparent distance from the Sun, comes on July 17, but the planet is actually a little higher above the eastern horizon before sunup a few days after that, as seen from the Northern Hemisphere.

Start looking for Mercury on July 7, when the planet lies about a degree from a thin waning crescent Moon. The Moon and Mercury come up only about an hour before the Sun on that day, so you will probably need binoculars to see them against the background of

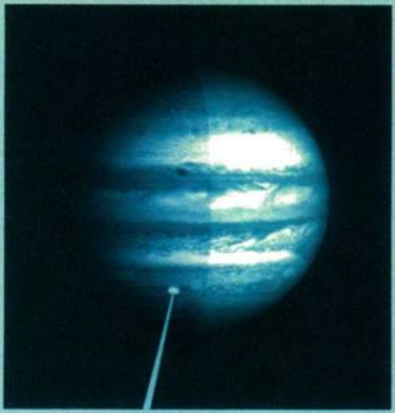
Venus Meets Regulus

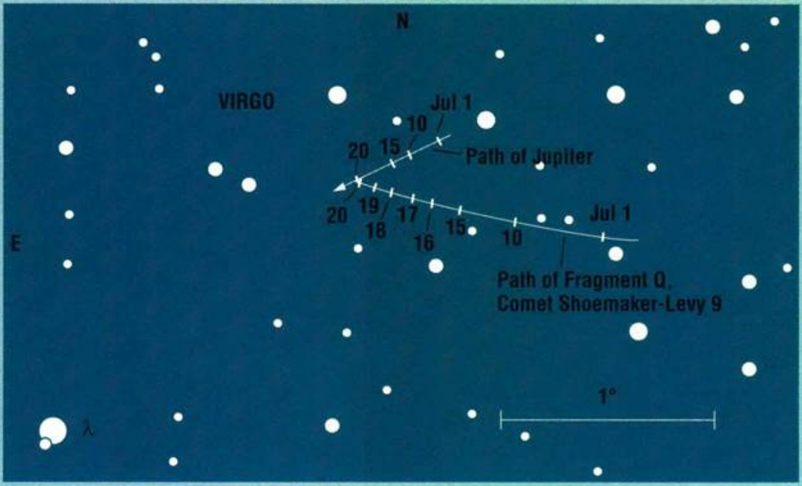
Venture out the evening of July 10 and look above the west-southwestern horizon. There, shining like a beacon through the twilight sky, is bright-white Venus. You also may notice a star just 1° to its south. That star is Regulus, normally one of the brightest in the spring sky. Now, however, it appears pale in comparison to Venus' glaring radiance. Venus spends a little time in Leo almost every year. Occasionally, as it does this year, the planet scoots past Regulus. This close passage should not be missed.

That same evening, try finding a young, slender Moon some 6° northwest of Venus and Regulus. Avoid trees and buildings — find a ballfield, rooftop, or hilltop. Binoculars will help bring out the faint crescent Moon, and they also provide a more dramatic view of the unusual appulse between Venus and Regulus. Both will fit in the same field of view.



The Great Comet Crash





Fallout from a Comet Strike

Phenomenon	Lifetime
Fireball	0-3 minutes
Ejecta falling back to Jupiter	Up to 3 hours
Seismic waves	Up to several hours
Atmospheric waves	Up to several days
Atmospheric effects such as cloud disturbances	Up to several weeks

(From 1994 University of Maryland Comet Workshop, provided by Reta Beebe, University of New Mexico.)

How to Find Shoemaker-Levy 9

	Offset from Jupiter	
On this date	West in R.A.	South in Dec.
July 1	3m2.3s	26'31"
July 10	1m58.0s	18'18"
July 15	1m15.8s	12'40"
July 16	1m6.2s	11'20"
July 17	55.9s	9'54"
July 18	44.9s	8'17"
July 19	32.4s	6'29"
July 20	—	—

(Comet's brightest fragment, called Q, represents the comet's position; collisions will occur between July 16 and 22. Positions courtesy Paul Chodas, Jet Propulsion Laboratory.)

NASA

Beginning July 16, for a period of slightly more than a week, the 21 large fragments (and a multitude of small ones) of Comet Shoemaker-Levy 9 will collide with Jupiter one by one. Last year astronomers Gene and Carolyn Shoemaker and David H. Levy discovered the comet, which appeared as a splintered "string of pearls." Other astronomers soon determined that the comet had passed close to Jupiter and been shredded. Moreover, they determined that its changed orbit would carry its pieces into the Jovian atmosphere in mid-1994. This month the compelling observational event, unique in recent solar system history, will finally take place. Will backyard observers and astro-imagers be able to see or record anything of these crashes? Perhaps.

Unfortunately the collisions will take place on the side of Jupiter facing away from Earth, so we will not have a direct view of them. The best we can hope to see are the effects of the impacts minutes to hours afterward, when the planet rotates enough to make the impact area visible. Therefore, most of the phenomena left in the wake of the crashes — the fireballs, fallback of the plumes of ejecta into the Jovian atmosphere, and seismic and atmospheric waves created in Jupiter and its atmosphere, will be difficult to detect. Another possible phenomenon, a brief flash from each impact visible as a momentary brightening of the Jovian satellites, will also be difficult to see. The increase in the brightness of the satellites will be slight, perhaps $1/10$th of one percent.

The best chance to detect the impacts' effects with backyard telescopes, astrophotography rigs, and CCD cameras comes with recording disturbances in Jupiter's cloud patterns the impacts will likely cause. Regardless of how you view or record the event, this means becoming thoroughly familiar with the cloud features that exist on the planet in mid-July before the impacts occur. You'll be looking for any changes in the regions of the impacts, between Jovian latitudes 40° to 50° S.

The times for each of the 21 major impacts range from 3:26 p.m. EDT on July 16 to 3:41 a.m. EDT on July 22. (See "All Eyes on the Big Crash," June 1994). The brightest and presumably largest fragment, designated Q, will strike Jupiter at 3:12 p.m. on July 20. Its path on the sky along with Jupiter's is shown in the map above.

bright twilight. Try looking half an hour before sunup. Mercury shines at 2nd magnitude on this morning, but over the following days it brightens. It reaches 1st magnitude around mid-month, when it's highest in the predawn sky.

July's Planets

Low in the west when the Sun goes down, **Venus** shines at magnitude –4.1 this month, and it will get brighter still. On July 10, 11, and 12, the Moon passes near Venus and the nearby star Regulus. A telescope reveals Venus as a waning gibbous world.

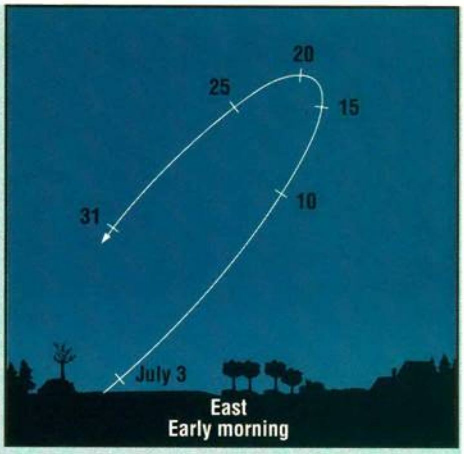
Jupiter is up in the southwest after sunset. It shines brightly at magnitude –2.2. This planet's slow retrograde, or westward motion, ends on July 2, a sign that usually indicates the most exciting months for viewing a planet have ended, but not so in this case. Telescopic observers should watch for changes in Jupiter's dark belts when the fragments of Comet Shoemaker-Levy 9 strike the planet in mid-July.

The constellation Libra and its attendant **Pluto** rise out of the south when night begins, lying not far from Jupiter. But while Jupiter outshines all the stars, Pluto, at magnitude 13.7, is a pinprick of light about a thousand times too faint to be seen with the eye.

Saturn rises in the late evening this month. The Ringed Planet appears as a steady golden light in the constellation Aquarius. By the end of July, it rises in the southeast while evening twilight glows in the west and brightens over the course of this month from magnitude 0.9 to 0.7. This signals Earth's approach to passing between Saturn and the Sun. Saturn's opposition, the time when it appears opposite the Sun as seen from Earth, will come in August. Look for Saturn near the Moon on the night of July 25.

A telescope reveals that Saturn's rings are slowly opening now, increasing from last month's minimum

Put Some Mercury in Your Morning

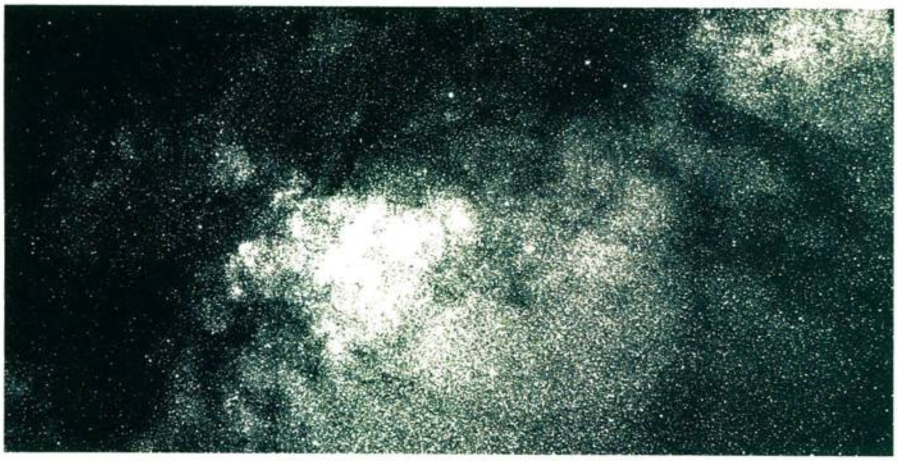


On July 17 Mercury moves into its third favorable apparition this year for observers in the Northern Hemisphere. On that date the planet reaches greatest elongation west of the Sun, separated from Sol by 21°. As Mercury reaches its greatest angular extent from the Sun in the middle of July, it sits in the best location for observers to spot this elusive body in the morning sky.

To see Mercury you'll need to wait until it rises high enough above the murky horizon. This should be half an hour or so before sunrise. Now located in the feet of Gemini and off Orion's "club," Mercury will soon begin heading back toward the Sun and a date with superior conjunction on August 13.

If you happen across Mercury early this month, you can watch its phase go from crescent (around the first week of July) to half at greatest elongation, to nearly full by August 1. In any case, fleetfooted Mercury doesn't stay in one place for long, so you can follow it from morning to morning. Take out a pair of binoculars to help spot the elusive planet. Once you find it you can look with the unaided eye and will see it easily when you know its position. You'll need a small telescope to see the planet's fragile phases, which range from a crescent to nearly full as the month progresses.

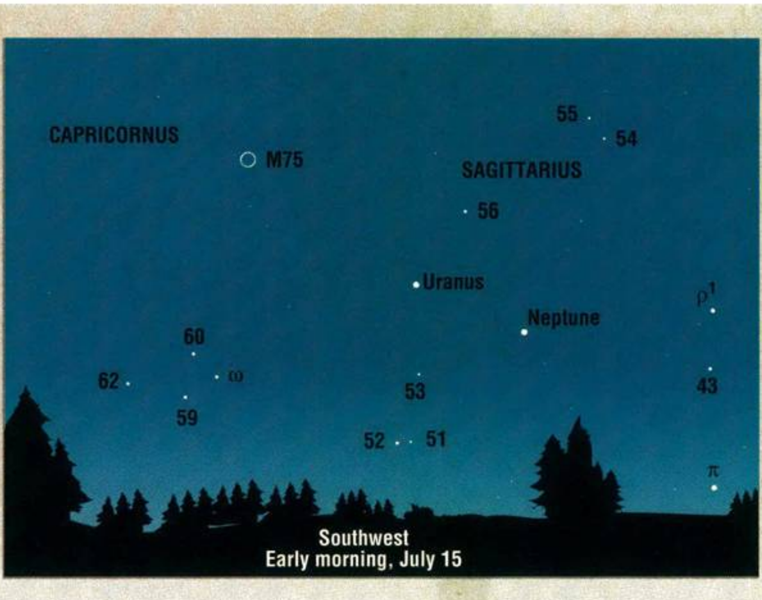
Scanning the Scutum Starcloud


Chris Cook

One of the richest regions in the sky is the Scutum starcloud. This large aggregation of stars indeed appears cloudlike to naked eye viewers. Follow the Milky Way "steam" rising from the Sagittarius teapot spout and you will drift into the cloud due east of Serpens. To the unaided eye from a dark site the starcloud appears as an isolated patch of powdery light punctuated by a handful of stars. But the region is best appreciated in 11x80 binoculars, for the entire dusty cloud appears brighter and more well-defined, and the lanes of dust that irregularly frame the cloud to its north stand out. It is almost as if the cloud were a floe of frosty light separated from the rest of the Milky Way. The cluster stands out in such striking contrast because it is surrounded by dark interstellar dust.

A cursory glance with binoculars along the eastern boundary of the Scutum Starcloud reveals something else quite remarkable: a bright, raggedy patch of light. This is M11, one of the most beautiful open clusters in the sky. Viewing this cluster with a telescope reveals a magnificent, compact assemblage of stars — similar to a globular cluster in its density of stars.

Uranus and Neptune at Opposition



The two outermost gas giants, Uranus and Neptune, are most favorably placed for observing this month as they reach opposition. The planets reach opposition on the 14th (Neptune) and the 17th (Uranus). "Favorably placed" means the pair rises at sunset and stays in the sky all night. Although they are technically their brightest at opposition (magnitude 5.6 for Uranus and 7.9 for Neptune), the two are only slightly brighter now than they are the rest of the year. They are so far away that Earth's little distance variations toward and away from them have little effect on their overall brightness.

For backyard astronomers, Uranus and Neptune have come to be test cases for the optical prowess of telescopes rather than exciting observing targets. These planets are just too far away to show cloud features or satellites, though large telescopes may reveal Neptune's largest moon, Triton, under exceptional seeing conditions and at high magnification.

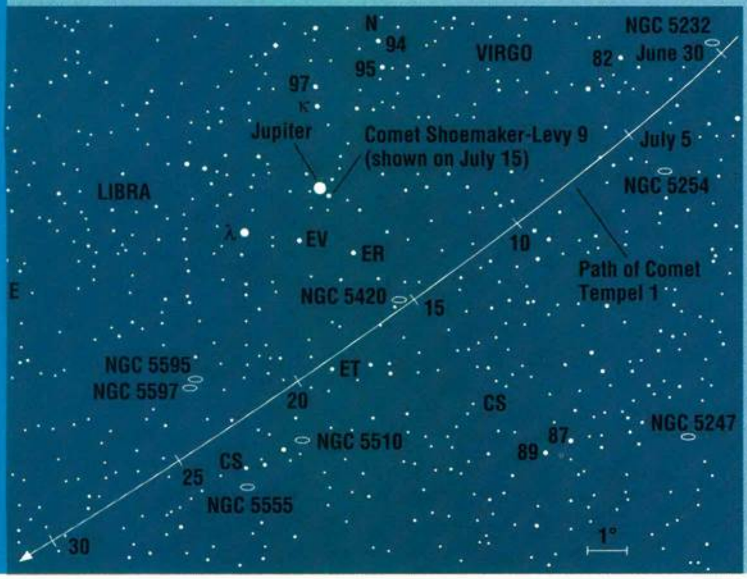
In a telescopic, both planets appear as tiny disks — Uranus being larger (3.8") and greenish, Neptune smaller (2.3") and more toward the blue end of the spectrum. You can glimpse Uranus under a dark sky with the unaided eye, though binoculars make it much easier. In a telescope, you can pretty well discern that you're looking at a disk. Neptune's disk, however, is not so apparent. You notice its color first, but it takes some moderate magnification and steady seeing to confirm that the colored dot is more of a disk than a point.

If at first you don't recognize either planet, focus your scope sharply and try again. The disks of these planets should look larger than the pinpoint stars that surround them.

Although last year's conjunction of these two distant worlds is over, they are still only a little over a degree apart in the sky, which is close enough to permit viewing both planets in the same low-power field of view. At opposition, Uranus' and Neptune's distances, are 1.7 billion miles and 2.7 billion miles, respectively.

Keeping Up with Tempel 1

The third brightest periodic comet this year, Tempel 1, still occupies a prime observing location in the evening sky. Throughout the month it moves through Libra, southeast of Jupiter. (The comet swings southeast of the Jupiter-Shoemaker-Levy 9 pair several days before the first fragments of the comet impact Jupiter.) The comet will remain fairly bright until late August, when it dims below magnitude 10. Tempel 1 begins the month 4° southwest of Alpha (α) Librae, known as Zubenelgenubi. Thereafter, it moves rapidly southeastward, slipping just a degree north of 3rd-magnitude Sigma (σ) Librae on the 16th. On the 31st, look for Temple 1 just 20' south of 3.6-magnitude Tau (τ) Librae.



Tempel 1 reaches perihelion July 3, when it should have a magnitude of around 9.2. By the end of the month, it drops to magnitude 9.6 or even 9.8. This region of sky is largely devoid of comet look-alikes, making finding the comet easy, although don't be fooled by NGC 5897, a faint globular cluster that stands about 5° east-southeast of Zubenelgenubi, well above Tempel 1's path.

In your eyepiece the comet will appear as a fuzzy patch of light distinctly different from the sharp, pinpoint stars surrounding it. A fuzzy outer glow, a coma, will envelop the comet's centrally located nucleus.

inclination for the year. Still, the trend is toward a more edgewise appearance of Saturn's rings in the coming year. In 1995, they will appear edge-on as seen from Earth and for a few months will seem to disappear.

The Red Planet, **Mars**, comes up in the east about three hours before the Sun this month. It still looks faint as seen from Earth and won't begin to brighten dramatically until this autumn, when we are closer to the time of passing between Mars and the Sun next February. Despite this, you can begin to observe it with a small scope.

This month it shines at magnitude 1.2 and resides in the constellation Taurus. The brightest star in Taurus is Aldebaran, sometimes called "the eye of the Bull." Aldebaran is an orangy-red star that forms an interesting color contrast with Mars. It is slightly brighter than Mars when the two have their conjunction, passing within 5° of each other on July 18. Also look for the crescent Moon near Mars on July 4 and 5. The Moon occults Mars on July 5 as seen along a band from southern Africa to southern India.

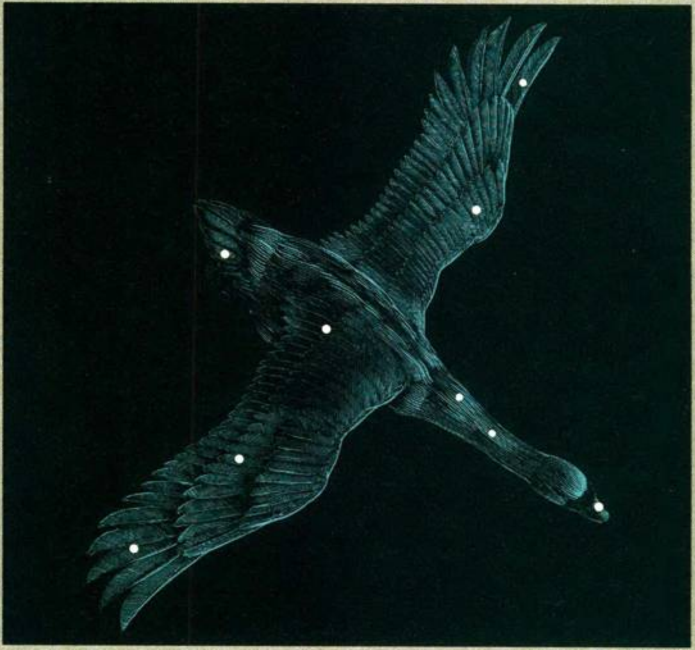
Elusive **Mercury** can be found to the lower left of Mars in the east shortly before dawn during the last three weeks of July. Mercury's greatest elongation comes on July 17, when it shines at magnitude 0.4. Around the end of July, look for Mercury near Castor and Pollux, the Gemini "twins."

Earth's aphelion comes on July 5. On that day we are farthest from the Sun for the year, at 94,470,000 miles. ☐

Deborah Byrd produces the Earth and Sky *radio series, which can be heard on more than 300 radio stations. Jeff Kanipe edits* Star Date *magazine, a publication of the McDonald Observatory in Texas.*

THE STARRY SKY

by Deborah Byrd



Keith Ward

Look for a large, starry cross high in the evening sky this month. On finding it you'll be gazing at an asterism known as the Northern Cross in the constellation Cygnus the Swan. The shape of the Swan is easy to imagine, too, though not so obvious as the Cross. The Swan flies southward, down the length of the Milky Way on summer nights.

A star named Albireo marks both the head of the Swan and the foot of the Cross. A small telescope turned on Albireo reveals it to be one of the sky's most colorful and lovely double stars, with one component blue and the other orange.

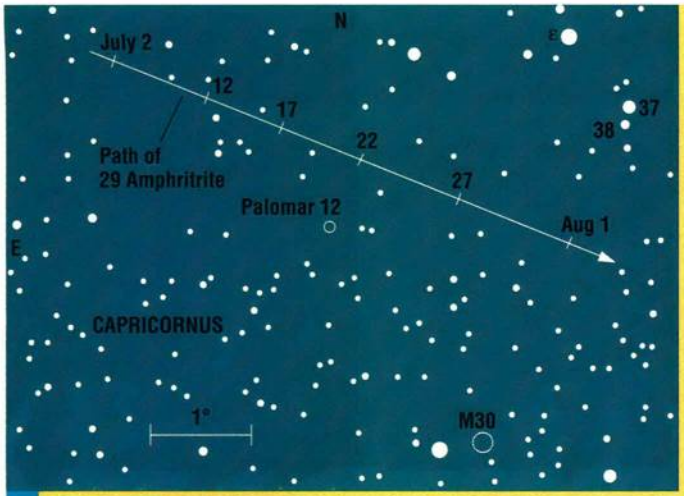
A very bright star lies at the head of the Cross, or tail of the Swan. This is Deneb, whose name means "tail." Deneb marks the northeastern corner of yet another asterism, this one made of three bright stars in three separate constellations. This large asterism, visible in the evening at this time of year, is called the Summer Triangle. The other two stars are Vega in the constellation Lyra and Altair in the constellation Aquila.

Deneb is one of the most distant of all the stars visible to the naked eye, at a distance of 1,600 light-years. That it is so distant and yet so bright means it's one of the most intrinsically luminous stars we see. Its mass is estimated to be about 15 to 20 times that of the Sun.

Deneb and the Northern Cross lie in a rich region of the starlit trail of the Milky Way. If you turn binoculars or a rich field telescope on this part of the sky, you will find many intricate and beautiful fields of stars. Look for the North America Nebula, a cloud of glowing gas and dark dust, whose shape can be seen through a telescope to resemble the continent of North America. Also, with the eye alone, notice the dark river — seemingly lacking in stars — dividing the Milky Way. This Great Rift is really a vast cloud of dark dust, a stellar incubator from which new stars will eventually emerge.

This constellation has been called a bird, hen, or swan by various cultures. In Greek mythology, Cygnus was a musician-king and a devoted friend of Phaethon, son of the sun-god Apollo. Phaethon one day convinced his father to let him drive his sun-chariot across the sky, but he lost control of the horses and wreaked havoc on Earth and in the heavens. The king of the gods, Zeus, hurled a thunderbolt at Phaethon, and the boy was killed instantly. His smoldering body fell into the river Eridanus. Cygnus plunged into the Eridanus and swam back and forth, diving again and again to find his friend's body. He was said to look like a swan in the water, searching for food. Apollo was looking on in sorrow, and raised his son's faithful friend to a place among the stars.

In another version of this myth, Cygnus wandered through a poplar grove on the banks of the Eridanus, mourning his friend's death. Finally, the gods pitied him so greatly that they changed him into a swan made of stars. Since then swans have been said to sing sad songs when they are about to die: hence the origin of our expression "swan song."



Following Asteroid 29 Amphitrite

In Greek mythology, the nymph Amphitrite was daughter of Nereus, the wife of Poseidon, and a goddess of the sea. This month, her namesake, the asteroid 29 Amphitrite, comes to opposition in another mythological sea creature, Capricornus the Sea Goat, where it is well placed to observe in moderate-sized telescopes.

Amphitrite is a 120-mile-wide silicaceous asteroid, a flying mountain large enough to displace all the water in Lake Michigan. This minor planet makes a circuit round the Sun every four years; a day on Amphitrite is slightly over 5.3 hours.

At its brightest, when the Earth-Sun-asteroid geometry is favorable, Amphitrite can reach 7th magnitude. But during this go-around, it will reach only magnitude 9. That's still pretty bright, considering most asteroids at their peak fall well below this value.

Throughout the month, Amphitrite moves southward through Capricornus, southeast of Delta (δ) and Kappa (κ) Capricorni. Fortunately, the starry background is not overly busy in this region, which should make locating and tracking this asteroid a fairly simple task. Refer to the finder chart for the asteroid's location throughout the month. At opposition, Amphitrite is a little over 2° southeast of Kappa. Locate the area in binoculars and then zoom in with your telescope using low magnification. You'll see a smattering of 8th-magnitude stars and a dusting of 9th-magnitude ones, but not enough to confuse you.

Sketch the stars in this region. Come back several hours later and compare the positions of the stars in your sketch. The "star" that jumps in position is 29 Amphitrite.

Asteroid 29 Amphitrite Positions

Date	R.A. (2000) Dec.	Mag.
July 2	21h55.2m –19°45'	10.0
July 7	21h53.7m –19°56'	9.9
July 12	21h51.6m –20°08'	9.8
July 17	21h48.8m –20°23'	9.7
July 22	21h45.4m –20°38'	9.5
July 27	21h41.4m –20°54'	9.4
Aug. 1	21h37.0m –21°10'	9.3

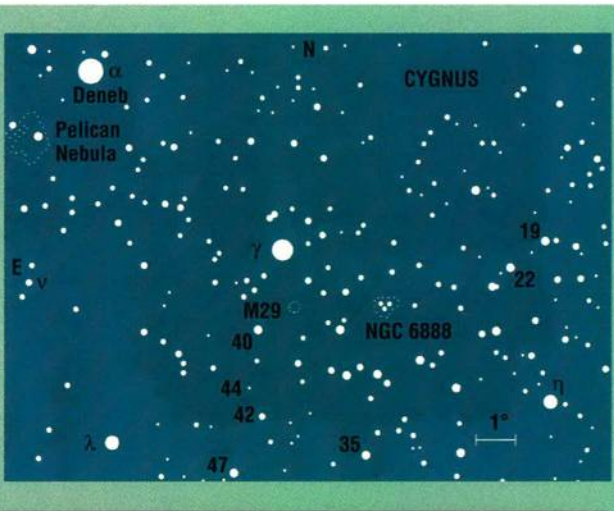
Hunt Down the Cygnus Bubble

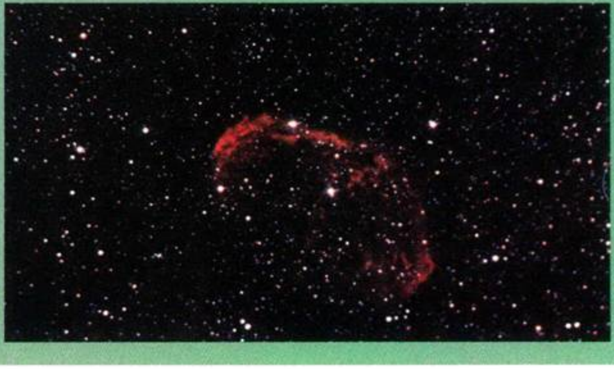
One of the more challenging objects in the Gamma (γ) Cygni nebular complex is NGC 6888, known as the Cygnus Bubble. Though similar in shape to the Veil Nebula to the east, the Cygnus Bubble is not a supernova remnant (like the Veil Nebula) but a glowing bubble of hot gas ejected from a Wolf-Rayet star. This unusual class of very luminous and hot stars is characterized by temperatures in the 50,000 kelvins range.

Astronomers believe these stars are the cores of very massive, O-type stars stripped of their outer envelopes. Much of the ejected mass of the original star is often visible as a ring or partial ring around the Wolf-Rayet star, and that is the case with the Cygnus Bubble.

The Cygnus Bubble is a delicate, filamentary nebula lying 1° northwest of 6th-magnitude 34 Cygni. A distinctive triangular-shaped group of stars of equal magnitude alerts you to the correct region. If you have a telescope with an equatorial mount, an easy way to pinpoint the region is to insert a wide-angle eyepiece and center on 31 Cygni (magnitude 3.7, west of Deneb). Next, simply slew southward 8¼° and then carefully shift the field slightly to the west and you will be on top of the Cygnus Bubble.

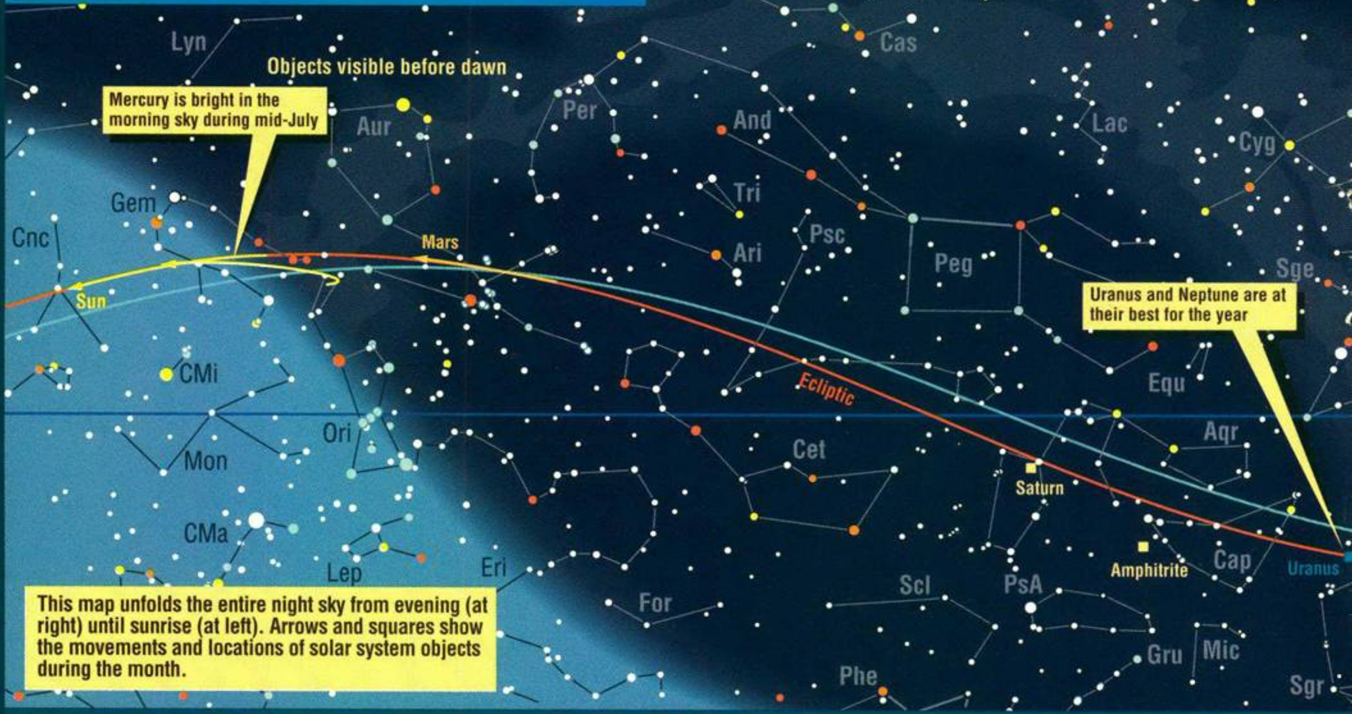
Of course seeing this nebula is more challenging than finding its location. The nebula's large angular diameter (20' by 10') translates into a low surface brightness that makes it a difficult object in a semi-light polluted sky. In small to moderate telescopes, the nebula's northern rim is the more apparent feature. You might also try looking for this object using 11x80 binoculars under a dark sky.



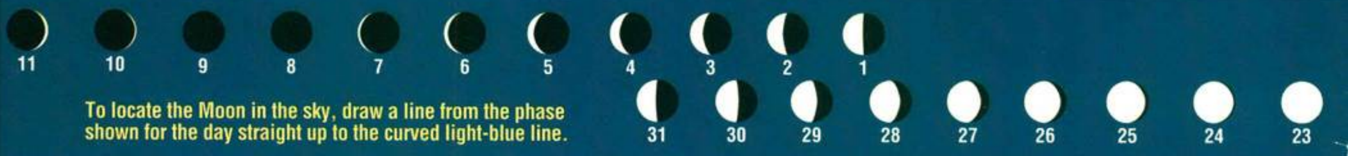

Jack Marling

SKY ALMANAC

JULY 1994


Objects visible before dawn
Mercury is bright in the morning sky during mid-July
Uranus and Neptune are at their best for the year
Lyn
Cas
Per
And
Aur
Lac
Cyg
Tri
Gem
Cnc
Ari
Psc
Peg
Mars
Sge
Sun
CMi
Ecliptic
Equ
Ori
Cet
Aqr
Mon
Saturn
CMa
Amphitrite
Cap
Uranus
Lep
Eri
Scl
PsA
For
Gru
Mic
Phe
Sgr

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.


11
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27
26
25
24
23

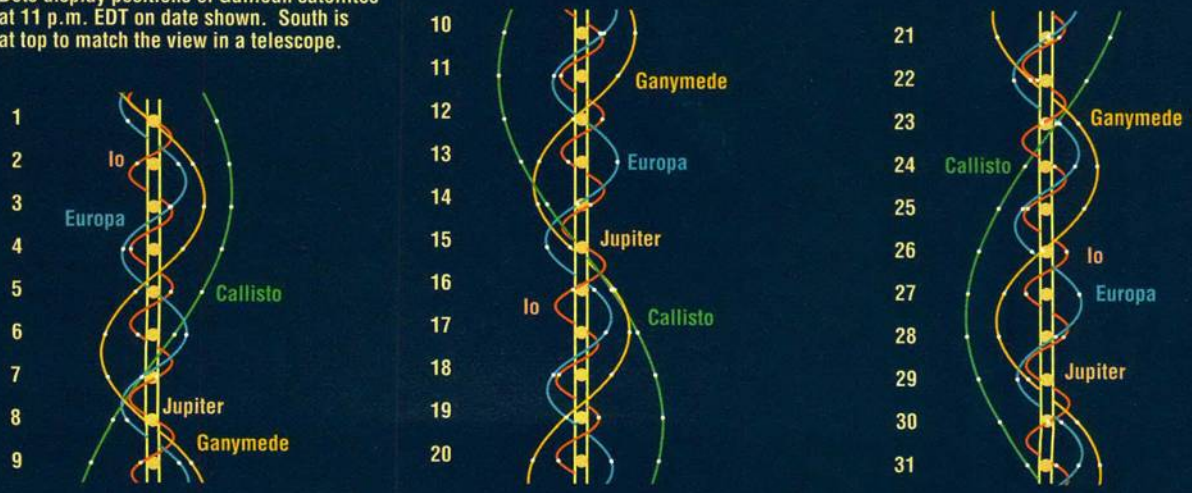
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

10"

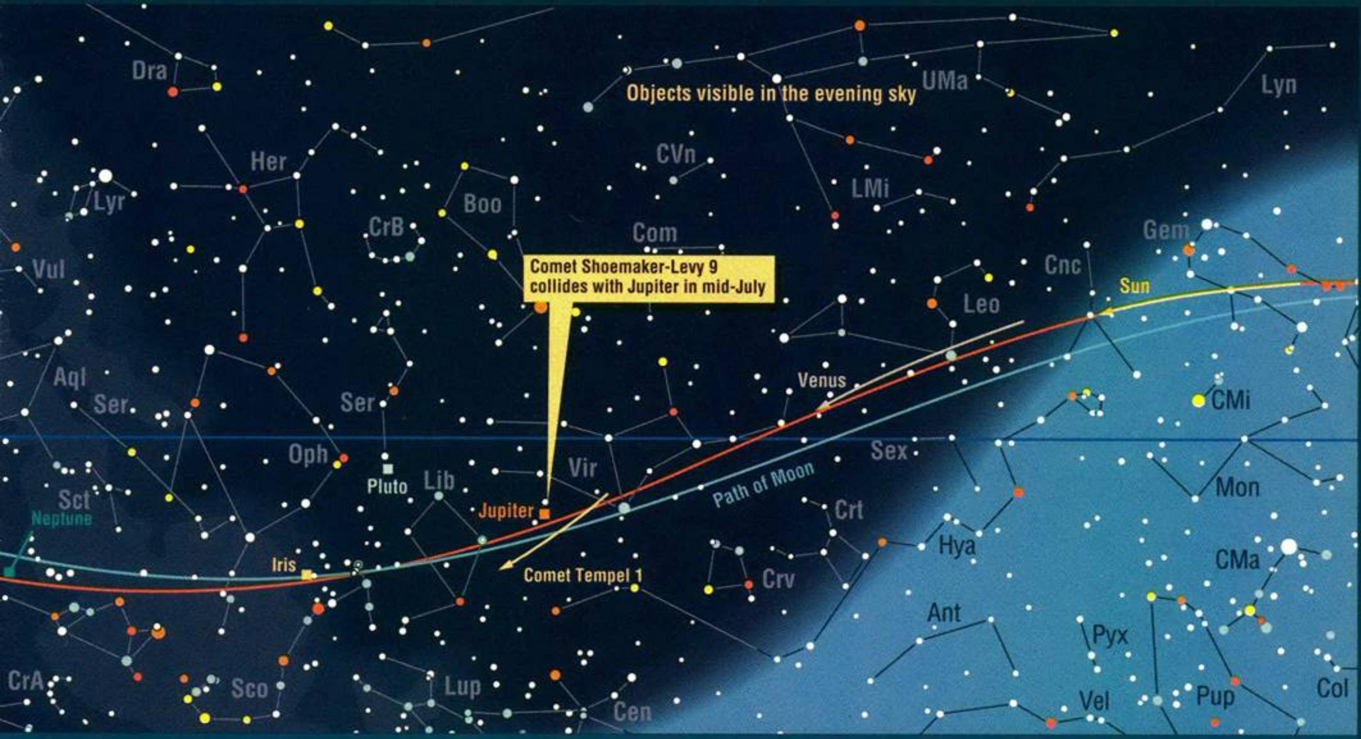
S
W — E
N

PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	July 15	July 31	July 1	July 15	July 15
Magnitude	0.7	–1.1	–4.0	–4.1	1.2
Angular Size	8.4"	5.7"	15.0"	16.6"	4.7"
Illumination	30%	81%	73%	67%	94%
Distance (AU) from Earth	0.801	1.176	1.111	1.006	1.985
Distance (AU) from Sun	0.383	0.309	0.722	0.724	1.448
Right Ascension (2000.0)	6h09.7m	7h42.5m	9h25.1m	10h26.3m	4h24.2m
Declination (2000.0)	20°16'	21°47'	17°05'	11°11'	21°21'

JUPITER'S MOONS



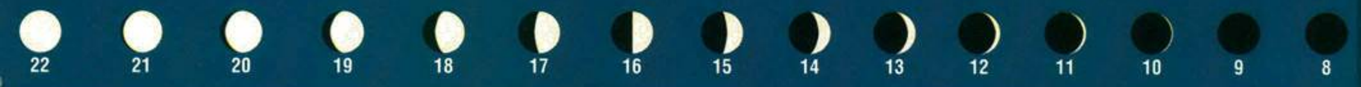
Dots display positions of Galilean satellites at 11 p.m. EDT on date shown. South is at top to match the view in a telescope.


Objects visible in the evening sky

Comet Shoemaker-Levy 9 collides with Jupiter in mid-July

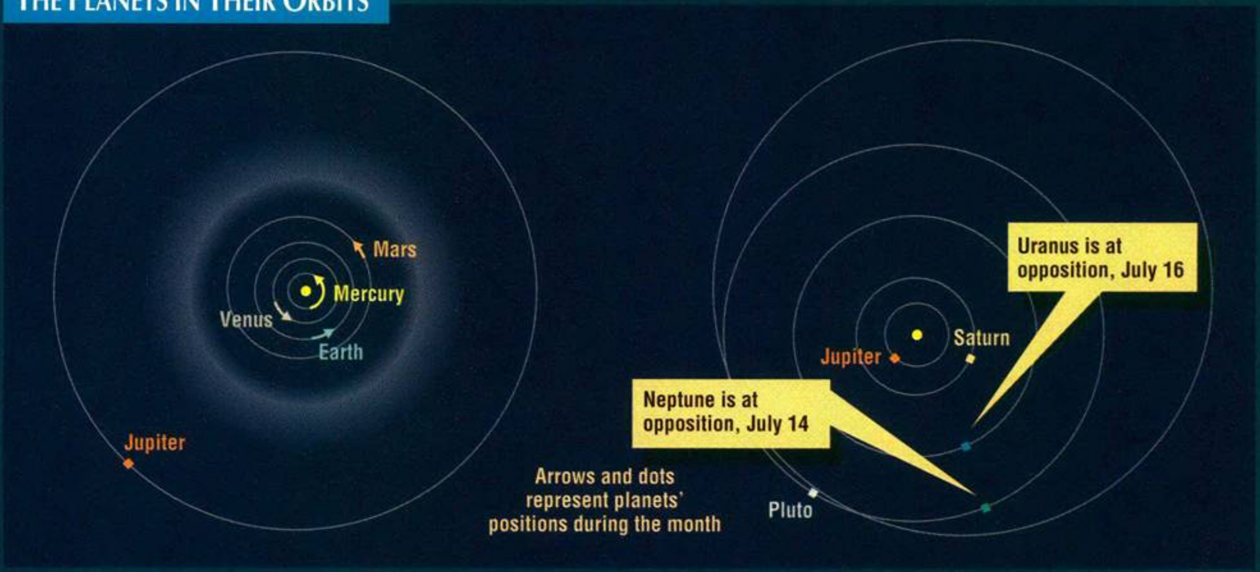
Comet Tempel 1

Dra
UMa
Lyn
Her
CVn
Lyr
Boo
LMi
CrB
Com
Vul
Gem
Cnc
Sun
Leo
Aql
Ser
Ser
Venus
CMi
Oph
Sex
Pluto
Lib
Vir
Path of Moon
Mon
Sct
Neptune
Jupiter
Crt
Hya
CMa
Iris
Crv
Ant
Pyx
CrA
Sco
Lup
Cen
Vel
Pup
Col


22
21
20
19
18
17
16
15
14
13
12
11
10
9
8

JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
July 15	July 15	July 15	July 15	July 15
–2.1	0.8	5.6	7.9	13.7
38.6"	18.4"	3.8"	2.3"	0.1"
99%	100%	100%	100%	100%
5.102	9.039	18.649	29.161	29.238
5.418	9.728	19.665	30.177	29.788
14h12.5m	22h56.5m	19h45.8m	19h34.5m	15h45.7m
–12°08'	–8°46'	–21°45'	–21°02'	–5°22'

THE PLANETS IN THEIR ORBITS


Mars
Mercury
Venus
Earth
Jupiter
Saturn
Jupiter
Pluto

Uranus is at opposition, July 16

Neptune is at opposition, July 14

Arrows and dots represent planets' positions during the month

TEST YOUR SCOPE'S OPTICS

Here's how to use a star at night — or an easy-to-build artificial star — to evaluate the performance of your telescope.

by David Bruning

You're interested in buying a used scope and want to know if the optics are really up to snuff. Or while attending a star party you view through a scope similar to yours and wonder why the images look so different. A simple test that will point out some basic ills of a scope or verify that it's working just fine.

Opticians use special test rigs to check the performance of a lens or mirror. But you don't need special equipment to check your scope's optics, just a star. Besides simplicity, star tests have another advantage over opticians' bench tests: You test the optics of the entire telescope, not just the lens or mirror. If you don't want to spend observing time some night on an optical test or prefer to test your scope conveniently during the day, you can build an artificial star from the directions given below.

Star testing provides a pinpoint of light that illuminates the objective of your scope evenly. Stars appear round because your scope's entrance aperture is round. But the image isn't a perfect disk. The lens or mirror creates what's called an Airy disk, which has a number of surrounding rings (see page 58 for an illustration of this pattern). British astronomer George Airy, for whom the central disk is named, first calculated the size of the disk in 1834.

ASTRONOMY: Darla Evans

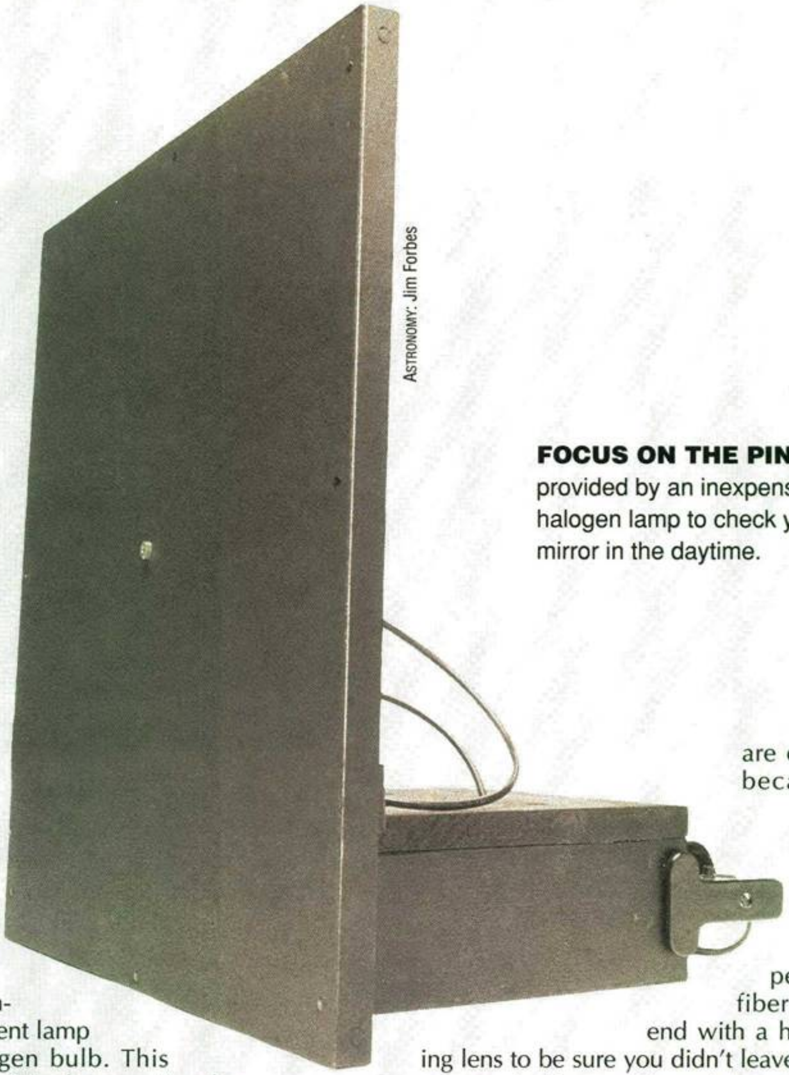
The Airy disk and the rings form because the edge of the scope's entrance aperture bends light. This bending, called diffraction, causes some of the light from the star to spill from the intense central disk into the bright rings. When the series of rings appears around the central disk with 87 percent of the light in the disk, 7 percent in the first ring, 3 percent in the second, and the remaining 3 percent spread among the other outer rings, the lens or mirror diffracts light perfectly. If the rings appear with different brightnesses or aren't round, then certain defects, called aberrations, exist in the optical figure of the lens or mirror.

A later section describes how to read these defects from the shapes and brightnesses of the rings, but first you need to find a star to use for the test. Try a 1st- or 2nd-magnitude star with 2- to 4-inch scopes and a 3rd-magnitude star for 16- to 20-inch ones. If the star is too bright, it will dazzle your eye and if it's too faint, you'll have a hard time seeing the rings.

Star tests would be easy if you could observe outside Earth's atmosphere. But for Earth-bound observers, the atmosphere blurs a star's light by a large amount. To test a scope, the amount of blurring must be less than the size of the Airy disk produced by the lens or mirror. That means you need to test your scope under steady, excellent seeing conditions; otherwise you might interpret the distortions introduced by seeing as defects in the optics.

Create Your Own Star

You don't have to wait for excellent seeing if you use an artificial star. This light source is bright enough that you can use it during the day. For their artificial star, some astronomers use sunlight reflecting off an insulator on a distant power pole or off a shiny Christ-



ASTRONOMY: Jim Forbes

FOCUS ON THE PINPOINT STAR provided by an inexpensive fiber optic and a halogen lamp to check your scope's lens or mirror in the daytime.

mas ornament hung in a tree.

Or you can make an artificial star simply using a lamp, a black card, some scrap wood to make a stand for the target, and a plastic fiber optic. Use an inexpensive clip-on accent lamp with a 50-watt halogen bulb. This lamp requires a 6- to 8-inch separation between the lamp and other parts of the tester because of the heat it generates. An open frame stand dissipates the lamp's heat safely and holds the black card used for the target. This card, cut from posterboard sold in art supply stores, is a little over 18 inches square, which is a big enough area to block out background objects when viewed through a scope with a high-power eyepiece.

The crucial part of the tester is the fiber optic. You can purchase suitable communications-grade fibers from Edmund Scientific or industrial surplus dealers. Edmund sells a 250-micron-diameter fiber that works nicely (#2541 costs $0.30 per foot and requires a minimum order of 10 feet). Its light-emitting region is slightly smaller than 250 microns, which beneficially makes the artificial star appear smaller.

When viewed through a scope, the fiber's diameter must be smaller than the scope's resolution element. For example, a 6-inch scope can resolve about 0.75" (4.5" divided by the scope's diameter in inches). To make a 250-micron-diameter fiber appear less than 0.75" across, it must be placed at least 225 feet from the scope. If your scope is larger, you must place it proportionately farther away. Or if you can get a smaller fiber, you can place the scope closer. Some fibers have diameters of 50 or 100 microns, so you can place the tester at 45 or 90 feet from a 6-inch scope.

Avoid glass fiber unless you can get a finished fiber of the proper length. Glass fibers are difficult to cut properly and need to be polished after cutting. Plastic fibers are easier to work with because you can cut them with a razor blade. Cleave each end of the fiber with a fresh part of the blade, keeping the cut perpendicular to the fiber length. Check the end with a high-power magnifying lens to be sure you didn't leave a jagged edge. You may need a few practice cuts to get a good fiber end.

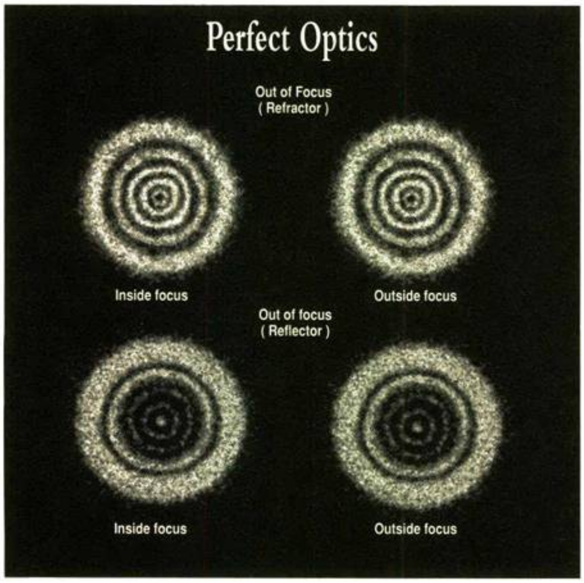
To protect the fiber, place it in a section of 1/8"-diameter air hose available from a hardware store. The ends sit in short 1/4x20 bolts, one mounted to the frame and the other at the target's center. Drill a 1/32" hole lengthwise through each bolt to take the fiber. The hose slips over the threaded end of the bolt. Paint the bolt head on the target face black to avoid glints of light off it.

Few of us have basements 200 or 300 feet long, so you'll probably have to use your star tester outdoors. Heat given off by the ground will introduce some optical distortion, but it won't be as bad as looking at a star at night through much more atmosphere. Nonetheless, you may want to test early in the morning before the ground warms up. Or perhaps you can use the hallway of your office building after work or that of a local school after classes.

Reading a Star

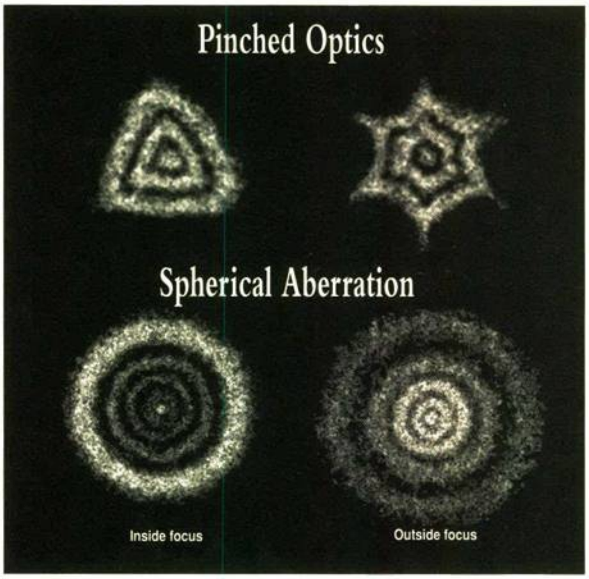
Whether you use a star at night, a fiber optic tester, or the glint of light off a distant object, the method of testing remains the same. First check your scope's collimation. (See "How to Collimate Your Telescope," April 1992.) This is a crucial step. Because a poorly collimated scope introduces coma and other optical distortions, it may mislead your reading of the star test. Next locate and center the "star" in your scope with a low-power eyepiece. Then switch to a high-quality eyepiece (not a cheap eyepiece that introduces its own problems into the test) that gives about 30 power per inch of aperture.

What Does Your Scope's Star Image Look Like ?



ASTRONOMY: Thomas L. Hunt

WITH A GOOD SCOPE you'll see a series of rings that appear the same on either side of the focus. Primarily an outer ring will appear in a reflector because the secondary mirror obstructs the light that forms the inner rings.



TWO COMMON PROBLEMS are pinched optics that make the rings angular rather than round and spherical aberration that causes the outer ring to change brightness inside and outside of focus.

Focusing the eyepiece should reveal not a single dot of light but an Airy disk surrounded by two or more rings. These rings should become crisp as the eyepiece passes through the focus. Defocusing the star slightly, you should see the rings enlarge. Now that they are larger, you may see more rings, perhaps as many as six. In a refractor, the outer ring will appear brightest and the other rings nearly the same as each other but weaker than the outer ring. (See the illustration above left.) A reflector shows mostly an outer ring, some observers liken it to a doughnut, because the secondary mirror blocks the light that forms the inner rings.

If the pattern of rings moves restlessly, then seeing is affecting your test. You should conduct the test on a real star only under good seeing or choose a time when ground heating won't affect the artificial star test. Tube heating can cause a flattened ring pattern or part of a ring to distort. Chances are you took your warm scope out into cooler outside air. Give your scope a half hour or so to match the ambient air temperature and then test again.

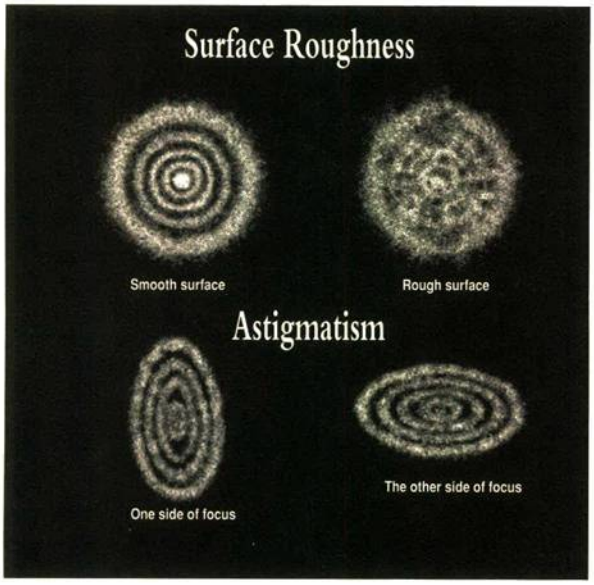
When you rack the eyepiece out of focus an equal amount but on the other side of the scope's focus, you should see an identical pattern. If not, you have a defect in your optics. Use the illustrations above to verify which one. You need to match the pattern's appearance on both sides of the focus to identify the optical problem. Reflector owners: Remember that your secondary creates a dark ring at the center of the pattern — don't let that fool you when interpreting your pattern.

Reflectors often suffer from pinched optics. The diffraction pattern looks like a three- or six-pointed "star." This tells you that the clips holding your mirror to its cell are pressing down too hard. Decreasing the pressure of the clips usually relieves this problem. If it doesn't, you may have a pinched secondary mirror. Unfortunately the secondary is often glued to its mounting, making it harder to fix.

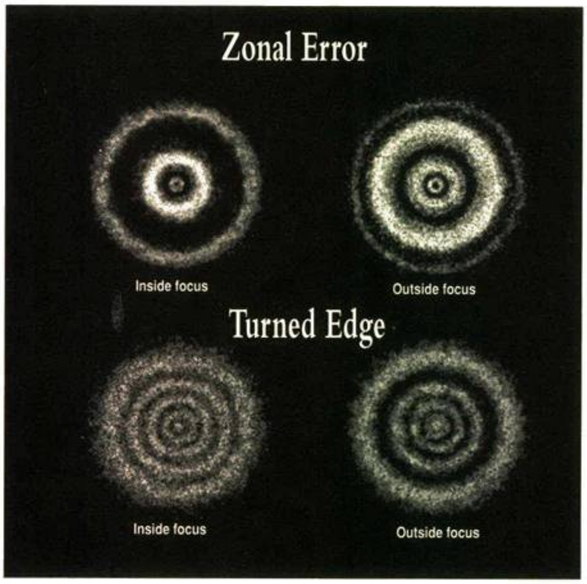
A common problem with many telescopes is spherical aberration. It's called spherical aberration because the surface of the lens or mirror is closer to a sphere in shape than to a paraboloid as it should be. When the light rays from the outer part of the optic focus closer than the focus of the inner region, it is undercorrected. When the light rays from the outer part of the optic focus farther than the focus of the inner region, it is overcorrected.

Inside of focus for an undercorrected lens or mirror (shown above right), the outer ring is brightest, reflecting that the outer parts of the optic are in focus. Outside of focus, the outer ring nearly disappears while the inner rings become brightest, reflecting that the inner parts of the lens or mirror are now in focus. An overcorrected lens or mirror shows the opposite pattern — a bright outer ring outside of focus and disappearing outer rings inside of focus. Stopping down your aperture by placing a ring around the outer edge of the lens or mirror can provide some relief. But if the spherical aberration is really bad, you need to have the mirror or lens refigured.

Rough surfaces produce star images that look like bad seeing but they remain stationary. The surface of the lens or mirror scatters light in all directions, causing the contrast to go down between the rings and dark surrounding regions. Your scope may be perfectly figured and capable of resolving perfectly, but it may never provide satisfying images because details will always ap-



LOSS OF CONTRAST AND DETAIL results from surface roughness because it scatters light throughout the image. Astigmatism causes a lens or mirror to focus differently in the vertical and transverse directions.



A RING DISAPPEARS on one side of focus when one portion (zone) of an optic focuses differently than the others. A turned edge shows normal looking rings outside of focus but washed out rings inside of focus.

pear washed out. If the mirror or lens is very rough, you should consider having the surface repolished.

Astigmatism occurs when the lens or mirror focuses differently in the vertical direction than in the transverse one. In the illustration above, the transverse direction focuses inside of focus while the vertical direction focuses outside of focus. Astigmatism reveals that the shape of the lens or mirror isn't symmetric about the optical axis of the optic — it's shaped more like a boat than a ball. Again, the only cure for this condition is to have the optic refigured.

But don't be fooled. Rule out a pinched secondary and uncollimated optics before worrying about astigmatic optics. You should also check that the problem isn't in the eyepiece or in your eye. Rotate the eyepiece to see if the pattern rotates with it. If so, it's in the eyepiece. Likewise, rotate your head to see if the pattern turns. If it does, you need glasses to see the best your scope can produce.

Star testing can uncover two other figuring errors: zonal errors and turned edges. Machine polishing can introduce a zonal error when the polishing tool works on one region too long or not long enough. The rest of the lens or mirror may focus light properly but the excessively or inadequately polished region may focus light at a different distance. This shows up as a weaker or missing ring on one side of the focus. Zonal errors can sometimes be solved by hand polishing but often require refiguring of the lens or mirror.

Turned edges result when the grinding or polishing tool exerts too much force on the edge of the lens or mirror and round it off. This happens because the optic supports the tool on one side but not the other. For a mirror, the outer edge no longer focuses light properly, so the outer rings disappear inside of focus. The large amount of light scattered inside the telescope decreases the contrast so the rings appear washed out. Outside of focus the ring pattern looks nearly normal. This pattern is reversed in a lens — the rings look washed out outside of focus and nearly normal inside of focus. A simple black paper ring that fits over the edge of the lens or mirror solves this problem.

Don't Panic

If you think you have a problem with your lens or mirror, take a time out. First check your results on another day. Also ask a friend, preferably a knowledgeable observer, to repeat the star test with you. Unsteady seeing or tube currents may have affected your first test. You should also star test some other scopes to build up experience before condemning a scope.

You should realize that all lenses and mirrors have some minor defects. If the defect is very apparent and the scope is newly purchased, take your results to the dealer or manufacturer and work with them to fix your scope. If you bought a used scope, an optician or the original manufacturer may be able to refigure the lens or mirror for you.

With any luck, your scope will check out fine with perhaps a trace of spherical aberration or some other minor defect that won't affect your viewing enjoyment. You should perform a star test from time to time to be sure that the mirror clips haven't tightened and started to pinch your mirror. It also provides a quick way to check your scope's collimation. But don't get so caught up with star testing that you forget to observe! □

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Meade 6" f/9 Model 152ED Refractor shown with #1697 Computer.

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Model 102 ED 4" f/9 Apochromat & mount (add $105 P&S)	**$2195**
Model 127 ED 5" f/9 Apochromat & mount (add $125 P&S)	**$2795**
Model 152 ED 6" f/9 Apochromat & mount (add $185 P&S)	**$4495**
Model 178 ED 7" f/9 Apochromat & mount (add $215 P&S)	**$5495**
Medium format adapters ..... Mamiya 645, **$98;** Pentax 6X7,	**$98**
Med. format EASY-GUIDER™: Mamiya 645, **$298;** Pentax 6X7,	**$298**

DRIVE SYSTEMS

#1664 Electronic Drive with PPEC & 2X, 32X slewing system	**$375**
#1697 Computer Drive, 747 object computer memory, automatic slewing to desired object	**$695**
8,000 Object CNGC Library .. **$99** Polar alignment finder ..	**$99**

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Model 102 ED/OTA 4" f/9 OTA only (add $55 P&S)	**$1045**
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Model 178 ED/APO-OTA 7" f/9 OTA only (add $120 P&S)	**$3250**
Cradle ring assem. 4" (4½" OD tube) **$135;** 5" (5½" OD tube)	**$145**
Cradle ring assem. 6" (7" OD tube) **$169;** 7" (8" OD tube)	**$219**

EQUATORIAL MOUNTS

LXD 600 mount and standard field tripod (add $60 P&S)	**$1350**
LXD 700 mount and giant field tripod (add $100 P&S)	**$2250**

NOTE: Add the indicated packing and shipping (P&S) costs to each telescope for insured UPS shipment to your door.

MEADE DOBSONIANS

Drop-shipped from Meade, add shipping charge in parenthesis.

6" f/8 Starfinder Dobsonian ($39)	**$295**
8" f/6 Starfinder Dobsonian ($49)	**$395**
10" f/4.5 Starfinder Dobsonian ($69)	**$565**
12.5" f/4.8 Starfinder Dobsonian ($79)	**$765**
16" f/4.5 Starfinder Dobsonian ($45)	**$995***

**Shipped truck freight collect; add $45 packing charge.*

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Select Any 3 . **$48.95 ea.;** Any 5 .	**$46.95 ea.**
Series 3000 40mm Plossl 1¼" eyepiece	**$79.95**

Shipping charges of 4-5% are extra.

NEW MEADE 12" LX200 SCHMIDT-CASSEGRAINS

8" LX200 $2295

NEW Meade 8" LX200 Telescopes

See the Meade ad in this magazine for full specifications & details. **LX100 Drive**, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") & dual-axis hand controller. **LX200 Drive**, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your Schmidt-Cassegrain.

8" LX100 Schmidt-Cassegrain with wedge (add $105 P&S)	**$1995**
8" LX200 Schmidt-Cassegrain with computer (add $105 P&S)	**$2295**
Wedge for photographing with 8" LX200	**$110**
10" LX100 Schmidt-Cassegrain w/super wedge (add $145 P&S)	**$2895**
10" LX200 Schmidt-Cassegrain with computer (add $145 P&S)	**$2895**
NEW! 12" LX200 (f/10 only) with computer (add $215 P&S)	**$3995**
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8,000 Object CNGC Library (Version 2.5 software)	**$99**
Library Option 1: 10,600 NGC, Messier, IC objects (Ver. 3.2 only)	**$99**
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Meade 2045D 4" f/10 with motor drive (add $40 P&S)	**$699**
Meade 2080B 8" f/10 with tripod, wedge, MCOG (add $85 P&S)	**$1149**
NEW! Model 2120B 10" f/10 w/wedge, tripod, MCOG (add $125)	**$1449**

PHOTOGRAPHY ACCESSORIES

LUMICON Cassegrain EASY-GUIDER 4", 8" only, f/6 or f/10	**$225**
LUMICON Giant EASY-GUIDER for 10" or 12" f/4-f/10 operation	**$395**

MEADE STARFINDERS

8" f/6 $699*

New 8" f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 25mm (=48X) eyepiece.

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8" f/6 Starfinder 8 (add $75 P&S)	**$699**
10" f/4.5 Starfinder 10 (add $90 P&S)	**$799**
16" f/4.5 Starfinder 16 (ship. freight COD)	**$2195**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $99 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

LUMICON Single axis drive corrector	**$99**
LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector	**$450**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

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LOW PRICE—from $399

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- "GUIDE" mode leads you to object
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- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

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NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

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IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

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Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2" EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

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2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6X7	**$129.00**
2" Adapter for Hasselblad	**$229.00**
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2" Extension for viewing	**$26.00**

2" DELUXE BARLOW

1.8x Multiplier Lens (2" Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow)	**$235.00**

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Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$119.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
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LOW PROFILE FOCUSERS New! Thread-on for Odyssey

FROM $59.50

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LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
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2" LUMICON EASY-GUIDER	**$169.50**

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Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$59.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
Large mounting rings for 80mm Finder	**$55**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$39.50**
1¼" 45° diagonal for correct left-right views	**$52.44**

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2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

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1" long 1¼" OD thread-in extension	**12.00**
2½" long extension (holds 1¼" filters)	**16.00**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces*	**$26.00**
2" long extension for 2" eyepieces*	**$26.00**

VIEWING ADAPTERS

2"/1¼" reducing bushing,threaded 48mm*	**$20.00**
2"/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
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**Threaded to hold 48mm filters.*

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ASTROPHOTO OF THE MONTH

Galaxy M-51 in Coma Venatici. 60 minute photo by Tony Hallas and Daphne Mount using hypered 2415 film, C-14 at f/7.5 with a LUMICON Giant Easy-Guider. *If it weren't for your accessories, these astrophotos wouldn't be possible,"* said Tony.

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

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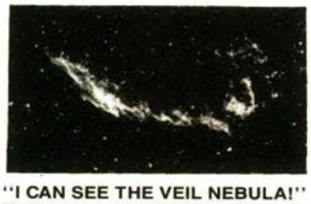
Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for ***reflection*** *nebulae."*
Astronomy, Feb. 1991

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0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$59.50**
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LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** ... **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines ... **1¼" $99.50, 48mm**	**$199.50**
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**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

"I'd Pick The TELE VUE™"

40mm Wide-Field Test, "Astronomy," Aug. 1990, p. 90

Genesis 4" f/5 4 element fluorite	**$1885**
Pronto 70mm f/6.4 apochromat w/2" diagonal	**$825**
Pronto 70mm f/6.4 w/45° erecting prism	**$725**
Renaissance-SDF 4" f/5.4, brass	**$2095**
Gibralter mount with ash wood tripod	**$495**
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	**$79**
1.8x or 2.5x Tele Vue Barlow Lens	**$89**
2" Giant Barlow - 2x	**$169**
32mm Plossl, widest true field in 1¼"	**$109**
55mm 2" Plossl, widest possible field	**$219**
15mm Wide-Field, 1¼" eyepiece, 65°	**$135**
19mm Wide-Field, 1¼" eyepiece, 65°	**$145**
32mm Wide-Field, 2" eyepiece, 65°	**$239**
40mm Wide-Field, "Rich-Field!" 65°	**$299**
4.8mm Nagler, 82° field, 1¼" eyepiece	**$149**
7mm Nagler, 1¼" eyepiece, 82° field	**$189**
9mm Nagler, 82° field, 1¼" or 2"	**$219**
13mm Nagler, 82° field, 1¼" or 2"	**$249**
12mm Nagler, Type II, 82°, 1¼"/2"	**$249**
16mm Nagler, Type II, 82°, 1¼"/2"	**$289**
20mm Nagler, Type II, 82°, 2" only	**$340**
1¼" Paracorr Visual Coma Corrector	**$159**
2" Paracorr Visual Coma Corrector	**$249**
NEW! 15mm Panoptic 1¼", 68° field	**$199**
NEW! 22mm Panoptic 1¼"/2", 68°	**$249**
NEW! 27mm Panoptic 2", 68° field	**$299**
NEW! 35mm Panoptic 2", 68° field	**$325**

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$39.50**	1.52"	**$45.00**	1.83"	**$49.50**
2.14"	**$59.50**	2.60"	**$75.00**	3.10"	**$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$165.00**

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.

LUMICON Adjust. Piggyback Mount **$59.50**
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$59.00**	**$49.00**
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U.S. Patent 4,473,636

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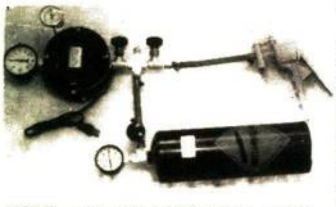

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D-19 B&W Developer	1 gal.	**$6.95**

Bring on the PHOTO CD REVOLUTION

This first of a two-part series looks at a technology that promises to breathe new life into astronomical slides and negatives.

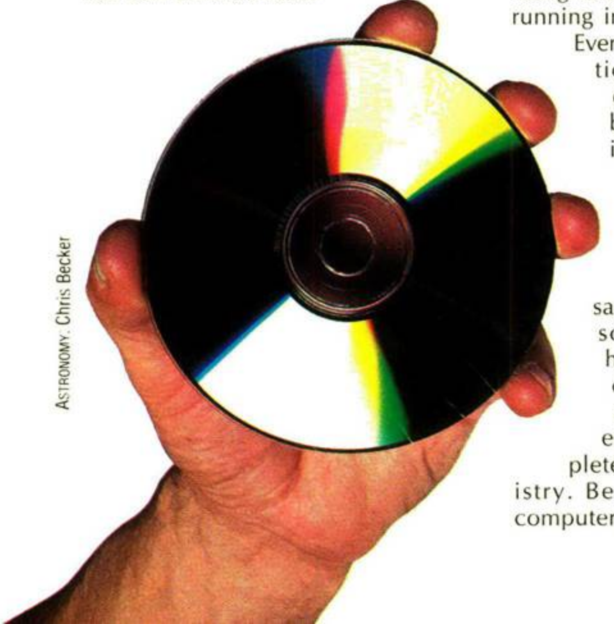
by Richard Berry

Astrophotographers, take heart — those thin negatives and dark slides, long the bane of many a photographer, can be converted into stunning astro-images. Thanks to home computer software, a "bad" astrophoto can be digitally processed to reveal everything locked away in its emulsion. Integral to this process is Kodak's Photo CD transfer, a service available at many camera stores that allows negatives and slides to be written to a CD-ROM. You can enhance astrophotos stored on Photo CD with a home computer using the same image-processing software that makes CCD imaging so powerful.

If you've ever done printing in a conventional darkroom, you're probably more than aware of the frustration involved in getting that perfect print. Dodging, burning, masking . . . all those techniques are difficult to master for one print, let alone multiples. Throw in the cost of chemistry and paper, and it suddenly becomes easy to fathom the beauty of manipulating astro-images with a computer running image-processing software. Every process, every manipulation nuance, can now be done at a computer keyboard. But like most things in life, the digital darkroom doesn't come without a price.

The right kind of home computer could cost you a couple thousand dollars, with the proper software adding several hundred on top of that. But compare those prices with the cost of outfitting a fully equipped darkroom, complete with (perishable) chemistry. Besides, a highly capable computer can do more than astro-processing, for there are hundreds of programs on the market related to astronomy that could use the computer's extra capabilities. But if you have the equipment and software, or the economic muscle to buy both, the digital darkroom may revolutionize your astrophotography forever.

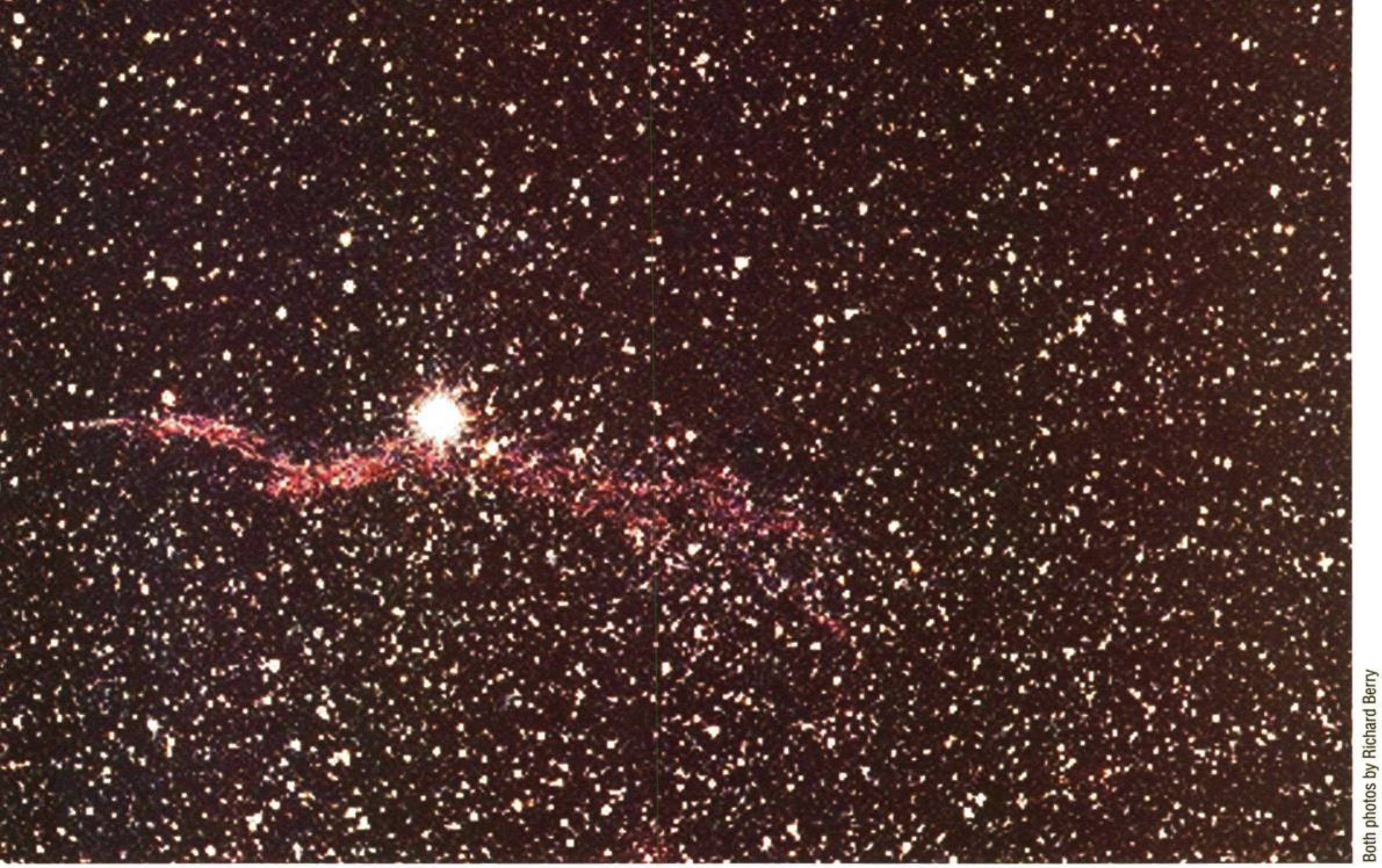
And it all starts with getting film transferred to a shiny, gold disk.



ASTRONOMY: Chris Becker

"Hows" and "How Much" of the Digital Darkroom

Here's how Photo CD works. You take your negatives or slides to a photo store that has Photo CD transfer equipment. The equipment consists of a scanning unit, a computer, a hard disk with large storage capacity, and a machine that can write digital data to a Photo CD, which is nothing more than a CD-ROM. (CD-ROMs are identical to the compact discs used for music, except that the disk has digital image information instead of music stored on it.) The operator places your film in the scanning unit and a few seconds later a low-resolution image appears on the computer screen. He or she can lighten or darken the image and shift the color, if the picture needs such corrections. When the picture looks good, the operator rescans it at high resolution (it



Both photos by Richard Berry

SUBTLE DETAIL AND SWIRLS OF COLOR came alive in this image of NGC 6960, the western lobe of the Veil Nebula in Cygnus, after it was transferred to Photo CD and enhanced on a home computer using image processing software.

takes just seconds) and stores it on the Photo CD. Up to 100 images can be copied to one disk.

Photo CD transfer prices vary considerably from retailer to retailer, but typical prices run $5 for the blank Photo CD plus $1.20 per transfer for 50 or more transfers. When all of your images have been transferred, you take the Photo CD home.

At home, you'll be able to view the Photo CD from your computer's CD-ROM drive. Be sure your computer has a CD-ROM drive that is multisession and Photo CD compatible. Today there are lots of CD-ROM drives for Macs and PCs, from the sluggish under-$200 Mitsumi, to the zingy $1,000+ triple-speed NEC and Sony drives. Any of them will do the job; the difference lies in the speed with which they load an image.

Images on the Photo CD are stored in Kodak's PCD file format. Image processing programs such as PhotoStyler 2.0 and PhotoShop 2.5 can directly open image files in the PCD format. If your software cannot open the PCD format, Kodak sells a low-cost utility called Photo CD Access (Eastman Kodak, 800-242-2424; list price: $39.93) that converts PCD-format images into TIFF, PCX, BMP, WMF, RIFF, or EPS formats. Photo CD Access allows you to convert the images and then open them with almost any image-processing software.

The PCD image format is remarkably versatile. For every picture scanned by your photo dealer, five image versions are stored on your Photo CD, from wallet to poster size. The wallet size images are tiny, just 192 by 128 pixels, perfect for a quick look. Next is the snapshot, twice as large as the wallet at 384 by 256, followed by the standard size, with 768 by 512 pixels and 16.7 million colors available per pixel. The large image size has a pixel array of 1,536 by 1,024, and the high-resolution poster size has an impressive 3,072 by 2,024 pixels. These image versions are stored within one file, which Kodak calls an image pack. Because the five images are compressed, 18 megabytes worth of data take only about 4.5 megabytes of storage space on the Photo CD. If your image-processing software supports PCD, you can simply select the image you want in the File Open menu and specify the size that you want, and the computer will display your photograph on the screen.

Armed with the powers of your image-processing software, you can alter the photograph by increasing or decreasing contrast, making it brighter or darker, or adjusting the color. If the picture has a bright greenish sky background, for example, you can remove the green cast and darken the sky to a more pleasing blue-black. If the picture is a bit fuzzy, you can sharpen it. You can also crop the picture, allowing a tiny region to fill the screen, or combine several pictures into a wide-angle view. You can also retouch specks of dust, remove scratches and other image defects, add a title, and label objects in your image. In short, you can do anything that modern image-processing software permits. But to make full use of all these powerful options, you will need the right equipment.

The heavy computational demands of image processing requires that you have a Mac Quadra or a PC

Films That Shine on Photo CD

Tech Pan 2415
Images crisp and sharp at poster size. Expose normally but do not process for extreme high contrast. Photo CD allows you to enhance contrast.

T-Max-400
Excellent grain in standard and large images. Expose and process normally. Photo CD allows you to enhance very subtle traces of nebulosity.

Tmax P3200
Very fast and very grainy. Photo CD permits you to control contrast and sky background to minimize graininess. Image processing software will allow you to minimize film grain.

Konica SRV3200
Rather grainy, but a fantastic film when hypered. Sensitive to red emission nebulae. Photo CD allows image to show rich, saturated colors in deep-sky objects.

Ektachrome 400
Good grain characteristics, tends to have a greenish cast that you can easily correct. High speed when processed in C41 chemistry as color negative and reversed in software.

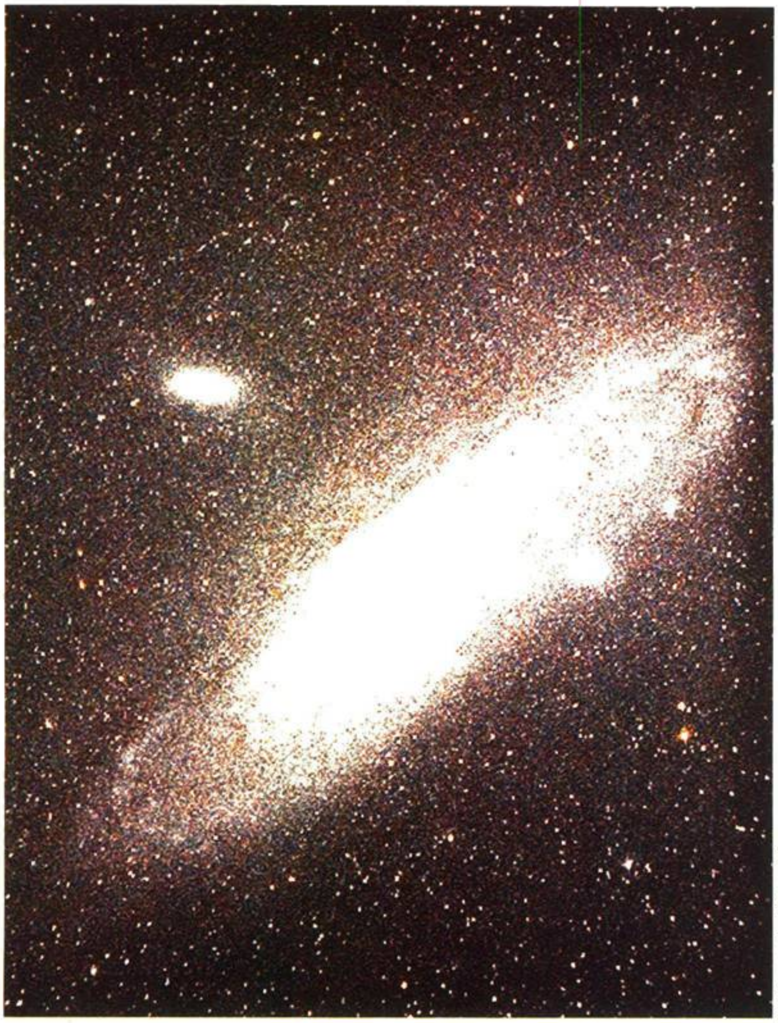
Fuji 400
Excellent both hypersensitized and straight. Good grain with high red sensitivity. Image-processing software allows it to be push-processed, and the resulting color errors can be corrected easily in software.

with a fast 486 or Pentium processor, a minimum of 4 megabytes of RAM (preferably 16 megabytes), and a large hard disk. It's also helpful to have an accelerated 24-bit (16.7-million color) display adapter and high-resolution monitor. You will also need 5 to 10 megabytes of free space on the hard disk for storing images. Although image-processing places heavy demands on system resources and processing power, today's computers offer more power for fewer dollars than ever before, and an imaging-capable PC need not cost more than $2,500.

The potentially high investment required to apply this digital technology revolves around one goal: improving marginal astrophotos that show promise. Half the battle in getting dramatic results is choosing the right negative or slide.

Only the Promising Make the Cut

To get your start in digital astrophotography, you first must select a group of photos that show promise but need help. The photos can be black and white negatives, color



THE GREAT ANDROMEDA SPIRAL lives up to its name in a photo boosted through home computer software. One enhancement technique conveys a more pleasing color and contrast balance (center), while another reveals subtle detail in M31's outer spiral arms (right).

Both images by Richard Berry

slides, color negatives (when negatives are scanned, the image stored on the Photo CD is positive), or color slides. All photos must be on standard 35 millimeter film. (Although Kodak can scan film formats up to 4x5 inches, this service is intended primarily for professional photographers.)

Here are some hints to help you select astrophotographs that will benefit from the transfer to Photo CD.

Use camera originals only. Even if the original negative or slide does not look as nice as the duplicate or positive made from it, you will get better results by scanning originals. Duplicate slides, slides made from negatives, black and white positives, and copies made from prints are second-generation products and contain considerably less information than first-generation originals.

Don't expect image processing to significantly improve photos that already satisfy you. If your original slides or prints from a negative look great, you will not do any better with computer processing. On the other hand, if you want digital copies for your friends or you want to see your best photos on a high-resolution computer monitor, scanning good-looking originals is a great way to go.

Select black and white negatives that have moderate contrast and sky density. The Photo CD scanner cannot extract information from very thin or very dense sky backgrounds and cannot capture the extreme density range present, for example, in push-processed Tech Pan negatives. To select a frame that has the right contrast and sky density, hold the negative an inch or two in front of type found in ASTRONOMY. You should be able to read the words through every part of the negative.

Avoid negatives that are uneven or suffer from faulty processing. Severe vignetting, for example, makes images difficult to enhance because vignetting is also enhanced. Commercially processed film is almost always uniform, but films processed at home often suffer from extra development near the edge of the frame or around the sprocket holes in the film. If you can see these problems in your negatives, they will limit what you can do to enhance the pictures.

Scan any color negative that shows signs of having an image, no matter how faint. Photo CD really shines with color negatives. The reason is that Photo CD was optimized for the long tone scale and soft rendition characteristics of color negative materials. And because almost all color negatives are machine-processed in photofinishing labs, color negatives are very consistent.

When you have selected a sample of your promising negatives and slides, call the nearest photofinishing company who does Photo CD transfers (to find one near you, look in the yellow pages under "photofinishing," or call Kodak at 800-242-2424, ext. 36). If you can, to be present when the transfers are made. If you live in a rural area, this could mean a trip to the city.

Transferring a Photo

The session at the photofinisher's begins by showing the operator your pictures and explaining what you hope to accomplish. Next, a blank Photo CD goes into the work station's CD-ROM writer.

After a quick inspection, the operator wipes the dust off your film with a chamois (or, for slides, uses a special vacuum cleaner), clicks the computer's mouse a few times, and then pops the film into the scanner. With a whir of stepper motors, the scanner inspects your film, and a moment later you see your picture appear on the operator's computer screen.

Much has already happened. The scanner has examined the image and determined how best to convert the film's full range of densities into a digital image. Variations in exposure, lighting, and density have all been factored. The image on the screen is the computer's best guess as to how your picture should look.

However, if the picture on the screen looks just like the original — pallid, weak, and washed out — the operator can make it darker or lighter, redder, greener, bluer, yellower, or add or subtract cyan and magenta.

THE GLORIOUS SOUTHERN MILKY WAY shines up after an originally bland negative is scanned onto a Photo CD, and then boosted using the tools found in image-processing software.

After tinkering until the picture looks okay (remember — you'll be making changes like these with your home computer), the modified image gets written to your Photo CD.

Because you plan to carry out further computer processing, it's a good idea to accept the computer's advice, since the image probably contains as much information as the system can extract from the original picture. If the picture looks okay, the operator clicks the mouse and writes the image to your Photo CD.

As one image after another gets written onto the Photo CD, think of the complexity of the task that happens so quickly. In the few seconds it takes to scan your film, the scanner generates data for a 6.3-megapixel array containing red, green, and blue data for each of the pixels, 18.9 megabytes of data for each 35mm frame. The system then converts the data from the red, green, blue colorspace to Kodak's YCC colorspace, neatly separating the luminance (brightness) for each pixel from its two chrominance (color) components.

The system then decomposes your picture into five images with different resolutions: the wallet, snapshot, and standard images are stored in their entirety, making them fast and easy to recall. The large and poster size images are stored as differences from values interpolated from the standard 768 by 512-pixel image; because the differences are generally small, this allows a high-resolution image to be stored in one-fourth the space an uncompressed image would require. As a result, your Photo CD holds 100 images rather than the 25 it could hold if they were uncompressed.

At the end of the session, the operator will make a print with dozens of thumbnail-sized images on it — a record of everything you have had transferred to the shiny gold compact disk — then pop the disk and print into a standard CD storage box.

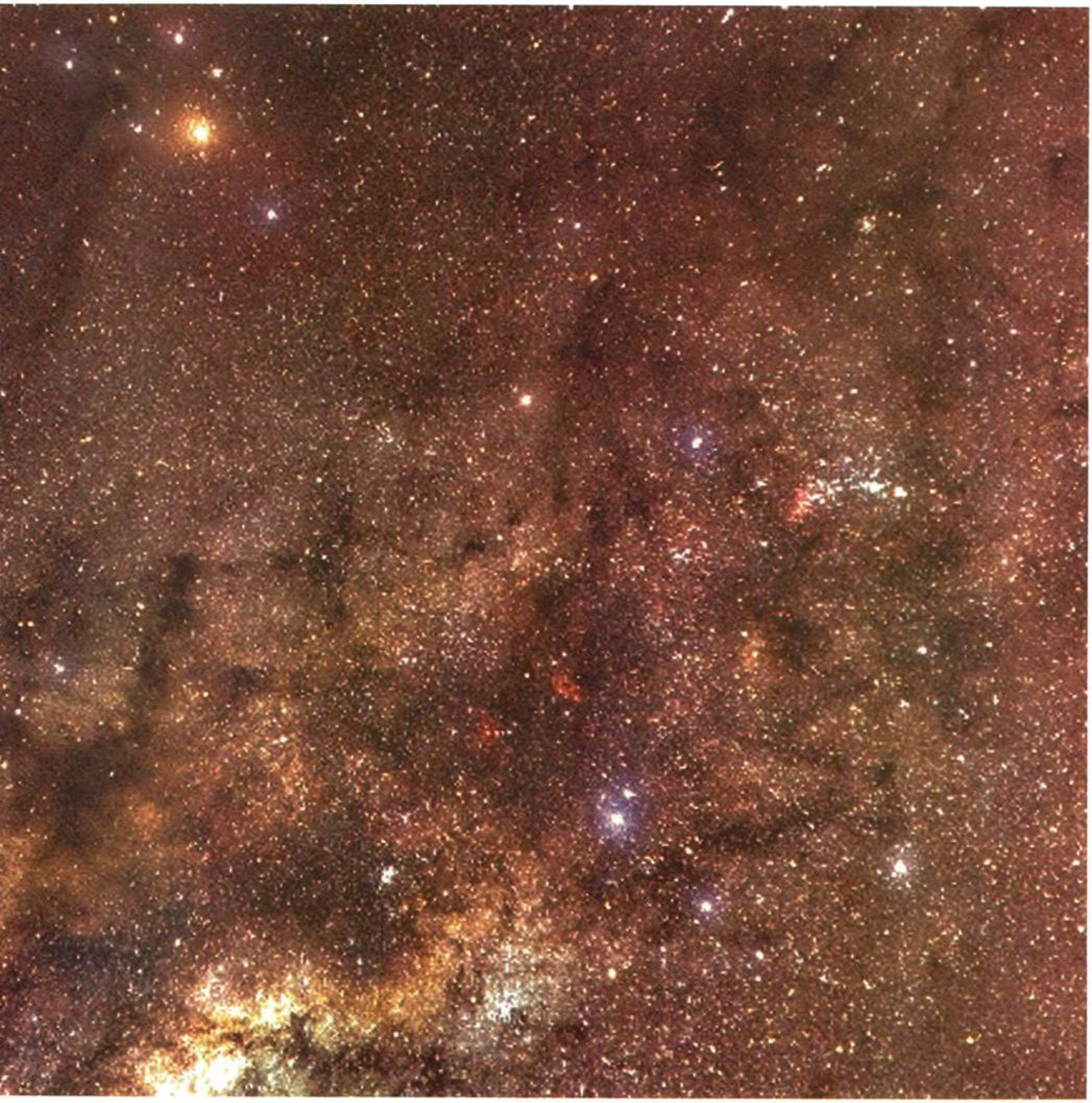
Image Processing from an Easy Chair

Once at home, you will be ready to use your new Photo CD for some electronic darkroom work.

After launching your image-processing software, find the command that opens Photo CD images. In PhotoShop 2.5 and PhotoStyler 2.0, you can open a PCD image with the Open command, just as you would any other image format. In PhotoStyler 1.1a, you can bring images in through the File Import Photo CD command. Even with today's relatively easy-to-use point-and-click software, it's a good idea to keep the manuals close at hand. PhotoStyler and PhotoShop are sophisticated programs, and they are too powerful to learn using the guesswork method.

For starters, open your Photo CD images at the standard 768 by 512 resolution. (Even this modest image size takes 1.2 megabytes of memory.) When you open an image, the access light on your CD-ROM player should come on, and some seconds later your astrophotograph should appear on the screen.

Examine the image carefully. Select the magnifier tool and enlarge the image by 4x or 8x, so you can see the pixels. Is the sharpness of the picture limited by the size of the pixels or by its natural fuzziness? If stars are two or three pixels across, there is no need to open a larger version of the image, but if the stars are square or



Both photos by Monte Wilson

blocky and limited by the pixel structure of the image, remember to open a larger version of the image at some time in the future.

Select the eyedropper tool. (This tool allows you to read the pixel value of the red, green, and blue components of the image.) Move the eyedropper over the picture. What are the lowest values and what are the highest? Considering that pixel values can range from 0 to 255, how much of that range do the pixels in the image occupy? Is it using the full range, or do most of the pixel values fall between, for example, 60 and 120?

To adjust brightness and contrast, use the Image Adjust (PhotoShop) or Image Tune (PhotoStyler) controls. Although changing the brightness and contrast is hardly a sophisticated way to process your image, the results are dramatic. Watch what happens when you raise the contrast and drop the brightness! All the hours you spent in a darkroom may suddenly seem futile — and you are looking at the least sophisticated control either program has to offer. Imagine what wonders lie in store for you!

In next month's article, you will learn how to perform three image-processing routines that consistently yield exciting results from negatives or slides that are flat, underexposed, and poorly color balanced, all done at your fingertips with a home computer.

This is the digital darkroom's true promise: Wringing every piece of information from a slide or negative, converting it to digital data, and then storing it on a medium, the compact disk, which will essentially last forever. Coupled with the image-manipulation muscle afforded by a home computer running image-processing software, the dawning of the digital darkroom just might be an astrophotographer's dream come true. ☐

Richard Berry specializes in CCD astrophotography and image processing. His latest book, The CCD Camera Cookbook, *describes how to build a CCD camera for under $300.*

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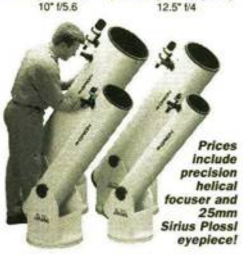

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Medium Case 12.5"x9"x5" #5952 **$26.95** (3.36)
Large Case 16"x11"x5" #5953 **$49.95** (5.19)

Orion® FlexiShield™ Dew Caps

Forms into a tube with Velcro closure, opens flat for storage and travel. Models to fit most telescopes.
8" Celestron/Meade SC #4200 **$44.95** (2.98)

Other sizes available for scopes 3.5" to 14"—See our catalog for details

Orion® Dew Zapper

Gently replaces lost heat, a sure-fire cure for dew problems.

8" Dew Zappers—fit all Meade & Celestron 8" SCs
DC #3503, AC #3504 **$47.95** (2.98)

10" Dew Zappers—fit all Meade 10" SCs
DC #3506, AC #3508 **$54.95** (2.98)

11" Dew Zappers—fit all Celestron 11" SCs
DC #3510, AC #3512 **$59.95** (2.98)

Scope Saver Telescope Covers

Keep the dust and dew away with these waterproof nylon covers; drawstring closure with cord lock.

8"Model #15130 **$33.95** (2.43)

10"-11" Model Fits Meade 10" and Celestron 11"
#15131 **$39.95** (2.43)

Now available for Deep Space Explorers!
Ask about other sizes.

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Standard Model—Adjustable height center column and padded seat.
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Deluxe Model—Built for professional musicians. Extra heavy duty.
#5934 **$89.95** (8.02)

Night Vision Flashlights

An essential accessory for astronomers. Choose from our wide selection.

Nitewriter Pen #5709	**$8.95** (1.79)
Hands-Free Flex Light #5707	**$17.95** (2.43)
Starlite LED Flashlight #5714	**$24.95** (2.43)
Celestron LED Flashlight #5720	**$21.95** (2.43)

Filters

Glass Solar Filters

High-quality optical glass filters, for superb images of the sun with your telescope. Triple-coated with advanced scratch-resistant stainless steel alloy. Great for both visual and photographic use. Slide fits over the front of your telescope.

For 8" SCs #7713 **$144** (4.05)
For 10" SCs #7715 **$162** (4.05)

NEW! *Solar glass filters for Deep Space Explorer reflectors. Many other sizes available—see our free catalog for details.*

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664, 1.25" #5662 **$14.95** (2.43)

Color Eyepiece Filters

Made from absolutely the highest quality photographic-grade precision-ground optical glass, anti-reflection coated. Ideal for contrast-enhancing planetary and lunar observations and photography with any telescope. The black anodized, machined aluminum cells thread into any standard eyepieces, or into our universal camera adapters.

.965" Basic Set of 4 Filters #80A Blue, #58 Green, #25 Red, #15 Yellow. #5510 **$46.95 set** (2.98)

1.25" Basic Set of 4 *#80A Blue, #58 Green, #25 Red, #15 Yellow.* #5514

1.25" Expansion Set of 4 *#21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.* #5516

1.25" Advanced Set of 4 *#8 Light Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green.* #5570

$48.95 each set (2.98)

Deluxe Set of 8 Filters for 1.25" Includes all the filters in our basic and expansion filter sets. #5517 **$84.95 set** (3.45)

Full Set of 12 Filters for 1.25" Includes Basic Set, Expansion Set, Advanced Set. #5575 **$124 set** (3.67)

2" Set of 4 Includes #80A Blue, #58 Green, #21 Orange and #12 Yellow. #5513 **$89.95 set** (2.98)

Individual .965", 1.25" & 2" Filters- Many colors available, see our catalog for details.

SkyGlow™ Light Pollution Filters

The finest available, SkyGlow™ filters from Orion make detailed deep-sky observing possible from light polluted city and suburban locations. Sophisticate multi-layer technology actually absorbs light pollution! Greater blocking and higher transmission than competitive models. See catalog for details..

SkyGlow UltraBlock Filters*–Visual Only*

For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter–fits 1.25" eyepieces. #5654 **$97.50** (3.45)
2" #5657 **$119** (3.67) .965" #5655 **$77.50** (3.67)

SC UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes. #5656 **$129** (3.67)

SkyGlow Broadband Filters—Photographic and Visual

For use in slight to moderately light polluted areas.

1.25" Broadband Filter–fits 1.25" eyepieces. #5660 **$69.95** (3.45)

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52mm Broadband Filter–For 52mm camera lenses, (Adapter rings available for other diameters.) #5668 **$87.50** (3.45)

2.0" Broadband Filter–fits 2" eyepieces. #5659 **$109** (3.45)

.965" Broadband Filter–fits .965" eyepieces. #5661 **$49.95** (2.98)

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Universal Camera Adapters

For prime focus or eyepiece projection astrophotography.

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1.25" #5264 **$28.50** (2.98)

Hybrid 1.25"/.965" #8782 **$28.50** (2.98)

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Allows variable projection distances during eyepiece projection photography. For 1.25" eyepiece holders.

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#7012 **$49.50** (2.98)

Extension Cable for Slow Motion Control

12 3/4" flexible cable, for tracking at high powers. Buy 2, one for each axis.

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For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

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Variable Tele-Extender #5127 **$37.95** (2.98)

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Threads to rear cell of telescope, requires t-ring for your camera model.

for SC #5116 **$26.50** (2.98)

for C-90 #7115 **$29.95** (2.98)

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Available for many different camera types, call toll-free or see our catalog for your particular model.

45° Erect Image Diagonal Prisms

See the world as it really is with Orion's 45° erect image diagonal. Ideal for all refractors and compound telescopes used for terrestrial viewing.

1.25" Diagonal #8790
.965" Diagonal #8791
Hybrid 1.25"/.965" Diagonal #8792

$44.95 (3.45)

90° Star Diagonal Prisms

Orion's multi-coated diagonals let you view at a right angle from the direction your telescope is pointing. The image is backward. Ideal for refractors and Schmidt-Cassegrains used for astronomical viewing.

1.25" Star Diagonal #8763 **$48.95** (2.98)

.965" Star Diagonal #8761 **$29.95** (2.98)

Hybrid 1.25"/.965" Star Diagonal #14008 **$31.50** (2.98)

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Your SC or refractor deserves the finest. Both models are the finest optical quality and use the best coatings available.

2" Prism Diagonal–Absolutely the finest quality multi-coated 2" prism for highest light transmission.

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- Built-in electronic sky catalog — find subjects by their common catalog name, not their coordinates. Complete with object descriptions.
- Powered by a single 9v battery. Weighs just 6 oz!

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Installation packages are available for most telescope models. Call for details.

starting at **$177** (5.29)

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Orion Off-Axis Guider

Allows you to observe a guide star during photography. Multi-coated.

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Wide-range lateral prism adjustment; precision helical focusing; adjustable camera focal plane position.

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Fits Orion equatorial mounts, many others. Plugs into any standard AC outlet.

#17001 **$72.50** (3.95)

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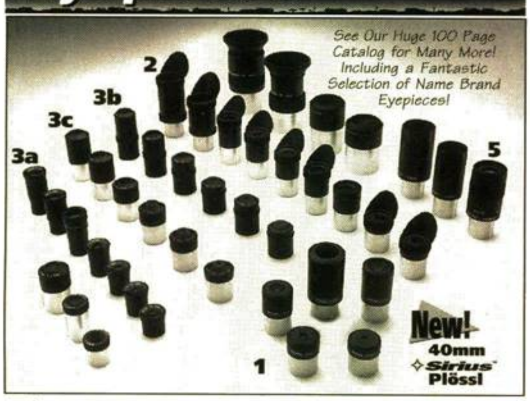
#2354 **$109** (8.97)

Eyepieces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3c
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1
New!
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You could pay nearly twice the price for "famous name" Plössl eyepieces, but we don't think you'll be able to tell the difference if you compare them to these fantastic eyepieces!

Sirius Plössls are top-quality, 50° apparent field (43° 40mm) eyepieces with extremely sharp images of impressively high contrast. Ideal for all types of telescopes. The Classic 4-element Plössl design is renowned for its fantastic performance and has become the standard by which all other eyepieces are compared.

The Fully Magnesium fluoride coated optics are mounted in precision black anodized aluminum housings with chrome-plated brass 1.25" barrels for durability and precision fit.

25mm #8530, ***17mm*** #8531,
10mm #8532, ***7.5mm*** #8533 **$57.95 ea.** (3.45)

New!- ***40mm*** #8529 **$77.95** (3.45)

Case only #5911 **$12.95** (2.19)

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Buy any two Ultrascopic eyepieces and get your choice of a 10mm or 7.5mm free! *Limited offer subject to stock availability.*

Orion 5-Element Ultrascopic™ Eyepieces

With superb Ultra™ Multi-Coatings!

Made for Orion by Japan's finest lens maker, Ultrascopic eyepieces yield the highest contrast, greatest light transmission, and best overall image fidelity obtainable. With a superior 5-element design and Ultra™ Multi-Coatings on *every* surface, they achieve a level of performance "name brand" 4-element models can't match. Wide 52° flat field of view. Removeable coutoured rubber eyeguard. The 5mm and 3.8mm feature advanced 7-element designs which yield surprisingly long eye relief. Absolutely guaranteed to knock your socks off!

Medium-High Power 5-element
20mm #8566, **15mm** #8568, **10mm** #8570, **7.5mm** #8572 **$89.95 ea.** (3.45)

Wide Field 5-element
25mm #8564 **$99.95** (3.45)
30mm #8562, **35mm** #8560 **$109 ea.** (3.45)

High Power 7-element *—Long Eye Relief*
5mm #8574, **3.8mm** #8576 **$99.95** (3.45)

3 Orion Explorer™ Multi-Coated 1.25" & .965" Eyepieces

These fine quality multi-coated eyepieces offer great performance at Orion's low direct-discount price. Three different optical designs are incorporated, to maximize efficiency in the various focal lengths. Black anodized, internally blackened, threaded for filters (except 40mm .965").

b *1.25" Orthoscopic*
5mm #8500, **7mm** #8502, **9mm** #8504, **12.5mm** #8506, **18mm** #8524, **25mm** #8526
$54.95 each (2.98)

c *1.25" Kellner*
6mm #8536, **9mm** #8538, **12mm** #8540, **18mm** #8508, **25mm** #8510, **40mm** #8512
$39.95 each (2.98)

a *.965 Orthoscopic*
5mm #8580, **7mm** #8581, **9mm** #8582, **12.5mm** #8583 **$49.50 each** (2.98)

a *.965 Kellner & Achromatic Huygenien*
K 18mm #8584, **K 25mm** #8585, **AH 40mm** #8586
$37.50 each (2.98)

Illuminated Reticle Eyepieces

A necessity for long exposure astrophotography and very useful for polar alignment.

12.5mm Plössl Illuminated Reticle 1.25"
Illuminator has fully adjustable brightness. Features double crossline reticle. Batteries included.
#8484 **$109** (3.45)

9mm Orthoscopic Illuminated Reticle 1.25"
Adjustable brightness illuminator. 'Bull's-eye within crosshairs' reticle. Needs 2 SR-44 batteries, not included.
#8488 **$119** (3.67))

12mm Kellner Illuminated Reticle 1.25"
Features double crossline reticle and red LED illuminator. Plugs into power panel drive bases.
#8482 **$74.95** (3.45)

12mm Kellner Illuminated Reticle 1.25"
Same as 8482 above except has a wireless illuminator. Needs 2 SR-44 batteries, not included.
#8481 **$94.95** (3.45)

SR-44 Batteries (pkg. of 2) #2360 **$5.69** (1.79)

5 UltraZoom™ 7–21mm

The finest zoom you can buy for your 1.25" telescope. For astronomy or terrestrial observing. 65°-35° field. Fully coated.

#8556 **$169** (3.67)

Barlow Lenses

Orion offers a large selection of barlow lenses, allowing you to double or even triple the power of your eyepieces, maximizing the versatility of your collection. Available in .965", 1.25" and 2" diameters.

Fully Baffled 2x Barlow
Multi-coated, with internal baffling to block transmission of stray light. Premium performance at a remarkable price.

.965" #8740 **$34.95** (2.98)
1.25" #8746 **$44.95** (2.98)
2" #8724 **$89.95** (3.95)

Ultrascopic 2x Fully Multi-Coated Barlow
3-element Ultrascopic lens for superior images and precise color correction. Fully multi-coated optics, black anodized barrel. 1.25 barrel.
#8750 **$64.95** (3.45)

VariPower 2-3x Barlow
Allows you to adjust the magnification factor of the barlow by sliding the internal cell along a calibrated scale. Fully multi-coated optics. 1.25" barrel.
#8748 **$57.95** (3.45)

Shorty Barlows

The short bodies allow extra versatility: provides 2x magnification when the eyepiece is inserted directly, and 3x magnification when positioned before the diagonal on a refractor or SC. Will work in all telescopes, including those where longer barlows won't work.

.965" #8710 **$39.95** (2.98)
1.25" #8711 **$44.95** (3.45)

Quality Components for Building or Upgrading

Parabolic Primary Mirrors

Excellent hand-figured parabolic mirrors guaranteed to meet theoretical limits of resolution. Fine polished, coated twice: with Aluminum and Silicon monoxide. Very competitively priced! *See catalog for pricing.*

Standard Primary Mirrors
Made from fine soda-lime plate glass, 1:8 thickness ratio. Guaranteed 1/8 wave. Sizes: 6" f/8, 8" f/6, 10" f/4.5, 12.5" f/6.

Pyrex Low Expansion Mirrors
Made from fine annealed Pyrex brand low expansion glass, 1:8 thickness ratio. Guaranteed 1/10 wave. Available with standard or 94% reflectivity Enhanced Aluminum coatings. Sizes: 6" f/5, 6" f/8, 8" f/6, 10" f/4.5, 10" f/6, 12.5" f/6.

Elliptical Secondary Mirrors

Made from fine annealed Pyrex brand glass, aluminized and SiO overcoated. Guaranteed 1/10 wave accuracy. Available with standard or high reflectivity Enhanced Aluminum coatings. Nine sizes from 1.00 to 4.00" minor axis.

See catalog for pricing.

6x30 Achromatic Finder Scopes

6x30mm—Same unit used on $1000+ "big name" telescopes. With 2-ring metal bracket, fits scopes 6"-12".
#13023 (white) **$49.95** (3.41)

6x30mm Right Angle—90° prism for right-angle viewing. Includes bracket.
#13021 (white) **$64.95** (3.41)

Large Aperture Finder Scopes

These are high-quality finders at incredibly low prices! Fully coated wide field achromatic optics with adjustable focus. Precision crosshairs. White or black enameled metal tube. (Mounts sold separatly.)

8x50mm—2.7x light grasp of 30mm models. Bright 6.25mm exit pupil.
#7090 (white) #7094 (black) **$64.95** (3.41)

8x50mm Illuminated—Wireless illuminator with adjustable brightness.
#7092 (white) #7096 (black) **$89.95** (3.41)

9x60mm — 44% more light grasp than 50mm models.
#7091 (white) #7095 (black) **$89.95** (3.41)

9x60mm Illuminated—Wireless illuminator with adjustable brightness.
#7093 (white) #7097 (black) **$129** (3.41)

Superb Dovetail Aluminum Mounts for 50mm and 60mm Finder Scopes

Instantly install or remove your finder, without tools, without disturbing alignment! Black anodized, Fits any scope 6" and over including Celestron & Meade SCs. *(pictured above)*

8x50mm bracket #5040 **$34.50** (2.45)
9x60mm bracket #5041 **$39.50** (2.98)

Low-Profile Helical Focusers

Economical yet precise focusing. Ideal for fast optical systems. Cast aluminum base with threaded machined aluminum inner tube.

1.25" #13014 **$39.50** (2.45)
2.0" #13016 **$59.50** (2.98)

Rack-and-Pinion Focusers

Finest in their class! Diagonal-cut plated brass racks, oversized knurled knobs, long focus travel.

1.25" #13007 **$49.95** (2.98)

2.0" includes 1.25" adapter.
#13003 **$89.95** (3.95)

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Oh Say Can

Take a celestial journey to deep reaches of the sky, guided by an experienced navigator.

By Jerry Spevak

On a clear, dark, moonless night, far away from city lights, the spectacle of the shimmering stars of the summer Milky Way is overwhelming. The stars are so numerous and bright it seems they might be touched, gathered up and bottled, like a cloud of fireflies. But these are not fireflies — each light represents a mighty sun.

The mighty suns appear as mere fireflies because of their immense distance from Earth. The closest star to the Sun is 4 light-years, or 25 trillion miles, away. Most of the visible stars are dozens or hundreds of light-years distant. The nearest galaxies beyond the Milky Way, galaxies impervious to the naked eye, lie millions of light-years off.

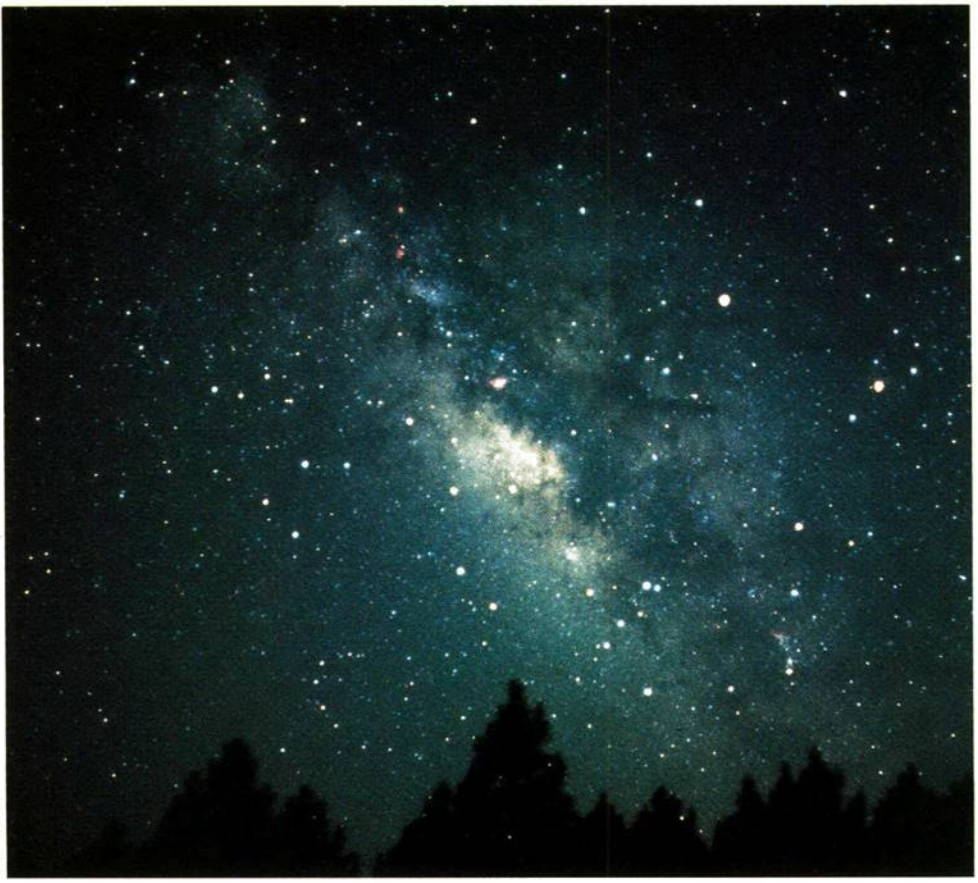
One night these vast distances became a challenge for me, an amateur observer interested in the deepest regions of the sky. I began to wonder how far I might see with the naked eye, how far with a pair of binoculars, and how far with the help of a large telescope to extend vision deep into the cosmos. So one day I assembled a list of objects that would test observing limits. The objects selected ranged from a few hundred light-years away to a few billion. The tour was such a success that I am inviting any of you other amateurs who want a summer sojourn through the skies to travel the same route. The trip to these objects will begin with the nearest and extend to the farthest. So pack up the binoculars and telescopes, and I'll guide you deep into the universe.

The Milky Way

The host of stars peppering the sky above belongs to the Milky Way. Assuming you live in or near a city, you're probably stuck with light-polluted skies. But fear not! Easily visible at magnitude 1.8, **Wezen** (Delta [δ] Canis Majoris, 7h08.4m, –26°24', epoch 2000 coordinates) is perhaps the most distant star visible to the unaided eye from an urban location. This powerful beacon is located well south of mighty Sirius. From my front yard, Wezen always flashes a rainbow of colors as it skirts the rooftops on cold winter evenings. Studies of its spectral features indicate that this supergiant shines with the light of 100,000 Suns across 3,100 light-years of space.

Under darker skies, the cosmic horizons expand considerably. In July Sagittarius sits majestically in the southern evening sky. Seek out the distinctive "teapot" asterism of Sagittarius and look well above the teapot's spout. You'll see a bright patch in the Milky Way designated **M24** (18h16.4m, –18°40'), a starcloud composed of the unresolved light from tens of thousands of stars in the Sagittarius arm of the Galaxy, the next spiral arm in toward the galactic center. Think of it as celestial steam!

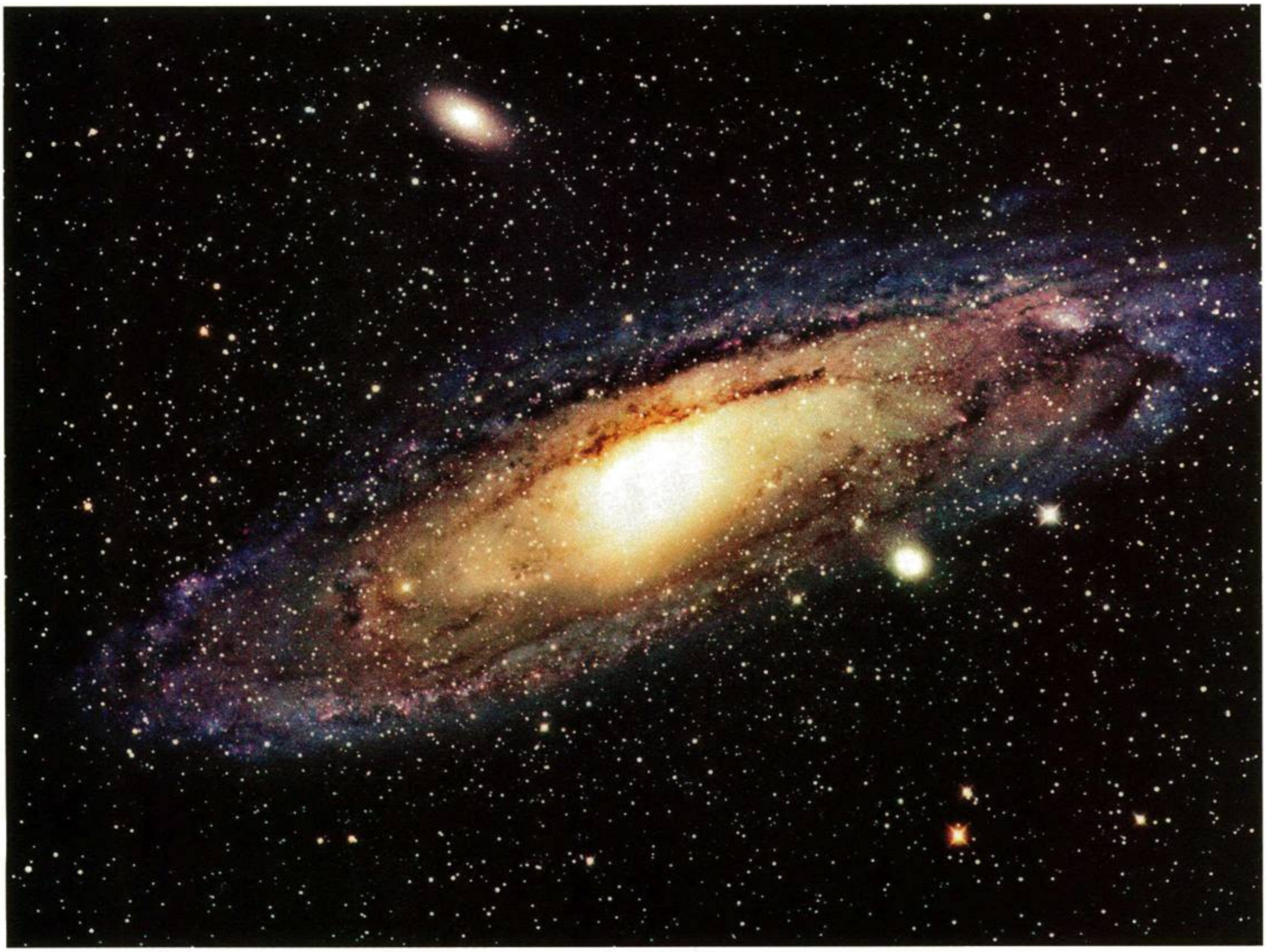
This fuzzy glow lies approximately 12,000 light-years away, more than halfway to the center of the Galaxy. (The center itself lies behind many light-years of dense dust, rendering it invisible.) As you see it, M24 measures 1° by 2° and shines at magnitude 2.5, giving it naked-eye visibility. With binoculars or a small telescope, you can observe innumerable stars in M24, a very rich field indeed. In its northern portion lies the compact cluster NGC 6603. (It's not clear whether or not the cluster is a foreground object.) NGC 6603 is partially resolved in my 70mm refractor at high power, and larger scopes reveal its remarkable richness.



Jerry Schad

THE BULGE OF THE MILKY WAY arches over the southern horizon on summer evenings. The fuzzy starcloud M24 (center), visible to the naked eye, lies some 12,000 light-years away.

You See?



Bill and Sally Fletcher

THE ANDROMEDA GALAXY, a spiral island of stars located 2.5 million light-years away, is the most distant object routinely visible to the unaided eye on a dark night.

Beyond the Milky Way

Let me now direct your eyes outward to galaxies millions of light-years away from the Milky Way, which is but one galaxy among billions. On early summer mornings, when the dew saturates the grass underfoot, if you look with eyes alone just 2° northwest of Nu (ν) Andromedae you should be able to make out a rather faint patch of nebulosity. This is the **Andromeda Galaxy** (M31, 0h42.7m, +41°16'). Along with the Milky Way, the Andromeda Galaxy anchors the collection of 33 mostly small galaxies in the Local Group, a cloud of objects some 4 million light-years across.

Astronomers studying the pulsations of variable stars in the Andromeda Galaxy place its distance at about 2.5 million light-years, making it one of the most distant objects visible to the naked eye. Indeed, it lies some 200 times farther away than M24.

Binoculars or a small telescope reveal the Andromeda Galaxy as an elongated haze several degrees across. Under pristine skies, I've traced it across 4° with my small refractor. Perhaps you can spot one or two dust lanes on the northern edge of the galaxy and a prominent star cloud southwest of the galaxy's core.

If conditions are just right, you may see another Local Group member with your eyes alone, although this one is far fainter than M31. Triangulum's **M33** (1h33.9m, +30°39'), sometimes called the Pinwheel Galaxy, shines at magnitude 6.3. To locate M33's position, imagine a line from M31 to Beta (β) Andromedae and extend it an equal distance. You'll need to employ averted vision, glancing slightly off to the side, to have a shot at seeing M33 with the naked eye. (This technique uses the rods of the eye, its faint-light detectors.) Despite its distance of 3.6 million light-years, M33 is easily swept up in binoculars, and a small telescope reveals a slightly mottled structure produced by clumps of stars and gas in the galaxy's arms.

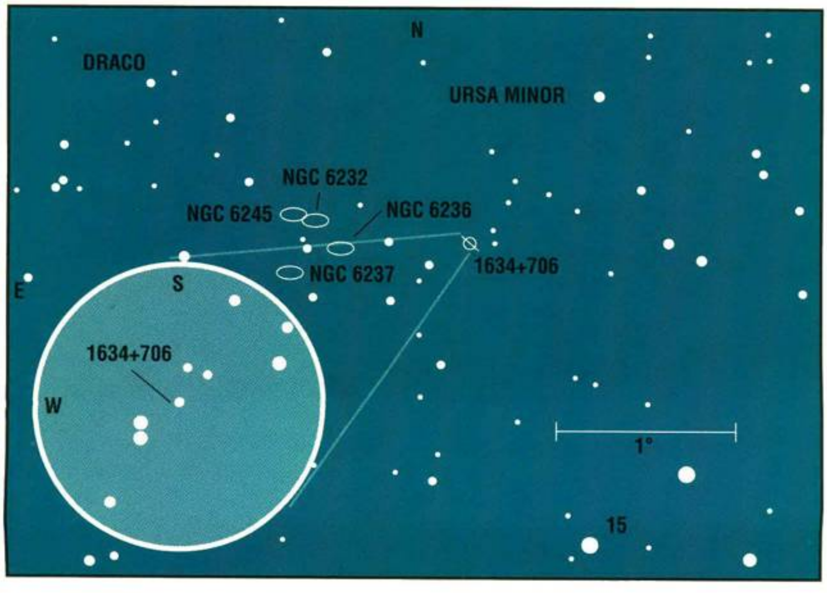
Kim Zussman

STEPPING OUT to the Virgo Cluster of galaxies means soaking in light that has traversed 50 million light-years, which requires a small telescope.

The Local Supercluster

The next stop of the tour is the realm of distant galaxies. As galaxies in the Local Group cluster together, so do those in the rest of the universe. In the constellation Virgo lies an immense cluster of galaxies, not coincidentally called the Virgo Cluster. Several thousand members have been identified on photographs taken with large telescopes, and many of the brighter galaxies are visible in 7x50 binoculars. The very brightest is **M87** (12h30.8m, +12°24'). This giant elliptical galaxy lies close to the center of the Virgo Cluster, a few degrees west of Epsilon (ε) Virginis. At magnitude 8.6, it appears as a diffuse glow with a bright core in my small refractor. A telescope equipped with a low-power, wide-angle eyepiece uncovers several other cluster members in the same field as M87. These include M84, M86, M89, M90, and M58. Pay very careful attention and you'll also pick up a few NGC galaxies. The whole cluster offers lots of enjoyment, for exploring it fully will keep you happily at your eyepiece many nights.

By measuring the rate at which galaxies appear to move away from us (called their redshift) astronomers estimate the distances to distant galaxies. The so-called Hubble Constant is a number that helps interpret the redshifts. Assuming a Hubble value of 23 kilometers per second per million light-years (astronomers' best compromise figure), the center of the Virgo Cluster lies about 50 million light-years away. Such a distance starts to lose its meaning when compared with the tiny measurements of everyday life. Just remem-



ASTRONOMY: Phil Kirchmeier

THE REALM OF THE QUASARS, consisting of the energetic centers of young galaxies, brings us significantly toward the edge of the universe. Quasar *1634+706 in Draco* is 6.3 billion light-years away and requires an 8-inch to 10-inch scope for viewing.

ber it's about 20 times more distant than the Andromeda Galaxy and 4,000 times more distant than the starcloud M24.

The Realm of the Quasars

Looking even deeper into the universe, beyond the superclusters, requires observing intrinsically brighter objects such as quasars. While giant elliptical galaxies are very luminous, quasars — thought to be the energetic nuclei of young galaxies — can be many times brighter. Since the discovery of the first quasar in 1963, astronomers have catalogued several thousand. Of these, **3C 273** (12h29.1m, +2°3') in Virgo, the first discovered, is the brightest. Appearing as a magnitude 12.9 "star," 3C 273 is a challenging object in anything less than an 8-inch scope.

To track down this and other quasars, you'll need a highly detailed map to differentiate it from the many nearby faint stars. This article contains maps for two extremely faint quasars; to find the others, consult *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi, and *A Handbook of Quasistellar and BL Lacertae Objects* by Eric Craine.

Although 3C 373 looks like a faint Milky Way star, it's many times more distant. Astronomers know it is receding from Earth at 15 percent the speed of light, which suggests it lies about 1.7 billion light-years away. This places it nearly 700 times more distant than the Andromeda Galaxy, some 140,000 times farther away than our starcloud M24.

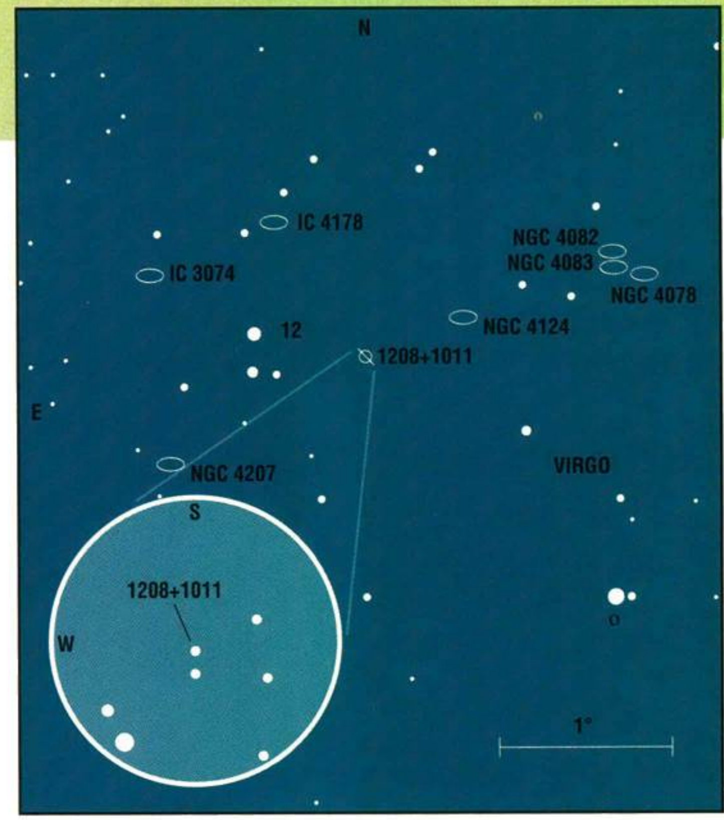
To take another large step out into the universe, consider targeting **1634+706** (16h34.5m, +70°32'). Located in Draco, this quasar can be observed on any night from the Northern Hemisphere. It has an apparent visual magnitude of 14.9, so it requires an 8-inch or larger scope for viewing. This object's redshift places it at a distance of 6.3 billion light-years and indicates it is speeding away from us at 70 percent of light speed.

The journey has now landed you in the mid-range of the universe. This object may be half or nearly halfway to the edge of the universe. It may appear like a faint star in the Milky Way, but that light began its journey across space even before the solar system formed, before the Sun was born. You're looking across a gulf of blackness some 2,500 times farther than the Andromeda Galaxy, nearly half a million times more distant than M24.

While you're still in Draco, take a peek at **1946+7658** (19h45.0m, +77°5'). Discovered in 1991, this quasar is a contender for the most luminous object in the universe. It outshines a large spiral galaxy like the Andromeda spiral by a factor of 10,000. Glowing dimly at just magnitude 15.8, 1946+7658 requires a 10-inch scope under normal conditions, although on two occasions I've seen it with an 8-inch scope. Don't be afraid to use high magnification when tracking down a quasar such as this one. High power reduces sky brightness and helps separate the quasar from a faint star that lies a few arcseconds northwest. At a distance of 7.6 billion light-years, 1946+7658 is a long way from home.

Going to the Edge

Finally, back down in Virgo lies **1208+1011** (12h11.0m, +9°54'). Discovered in 1986, 1208+1011 was for a time the most distant object known. Because it glows extremely faintly, at magnitude 17.5, this quasar requires a large telescope to be viewed, photographed, or captured with a CCD. I've used a 16-inch reflector and found 1208+1011 a difficult object even at high power. Adding to the challenge, a 17th-magnitude star lies a few arcseconds north of the quasar. (I never thought I'd be bothered by the glare from a 17th-magnitude star, but when you're digging deep, everything counts.) This elusive object lies about 7.9 billion light-years away. That places it 3,000 times more distant than the Andromeda Galaxy and more than 650,000 times farther away than the starcloud M24.



ASTRONOMY: Phil Kirchmeier

DISTANT QUASARS mark the most remote objects in the universe. At a distance of 7.9 billion light-years, quasar 1208+1011 in Virgo requires the largest backyard telescopes for a visual sighting.

Astronomers discover more distant quasars every year. The early 1990s have witnessed the cataloguing of quasars receding at nearly 95 percent the speed of light. Such objects glow faintly at magnitudes of about 20 so they present a challenge to the largest backyard scopes.

Yes, actually, I do have a large telescope, but I learned something the night of my tour that I hope you've learned from the tour you've just taken. My observing notes had convinced me I could go further than I had with the naked eye, binoculars, or a small telescope. So after my tour was over, after I'd sojourned from the comfort of the Milky Way to the outer reaches of distant quasars, I packed up the scope and put away the list. I had mastered celestial travel and so, now, have you. ☐

Jerry Spevak is an enthusiastic observer living in Richmond Hill, Ontario who enjoys going for the remotest of deep-sky game. His last article was "Night of the Deep-Sky Observer" (March 1993).

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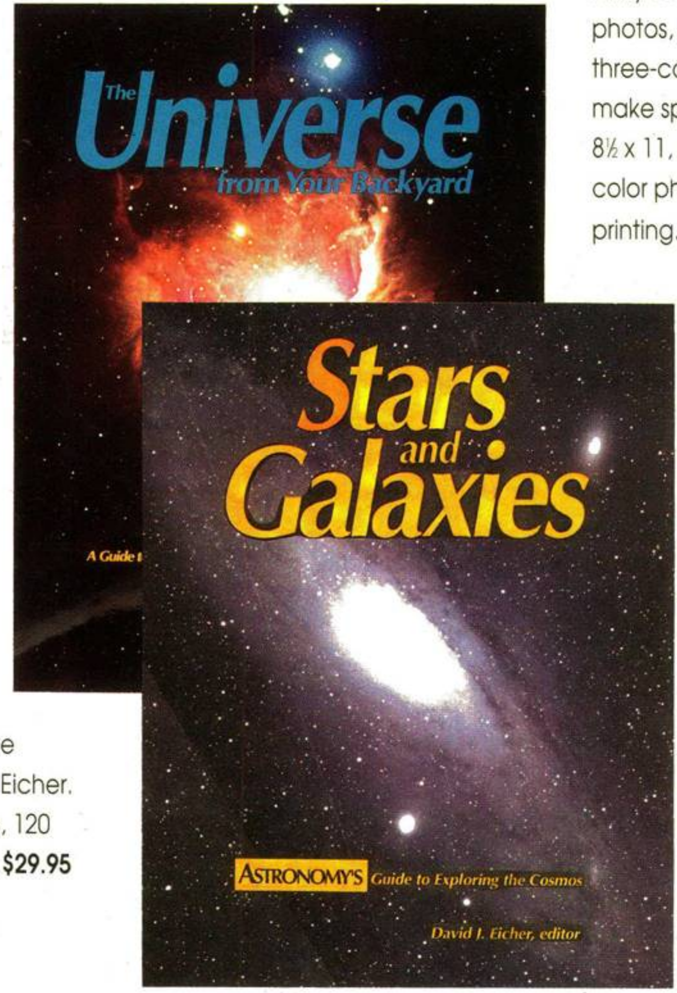
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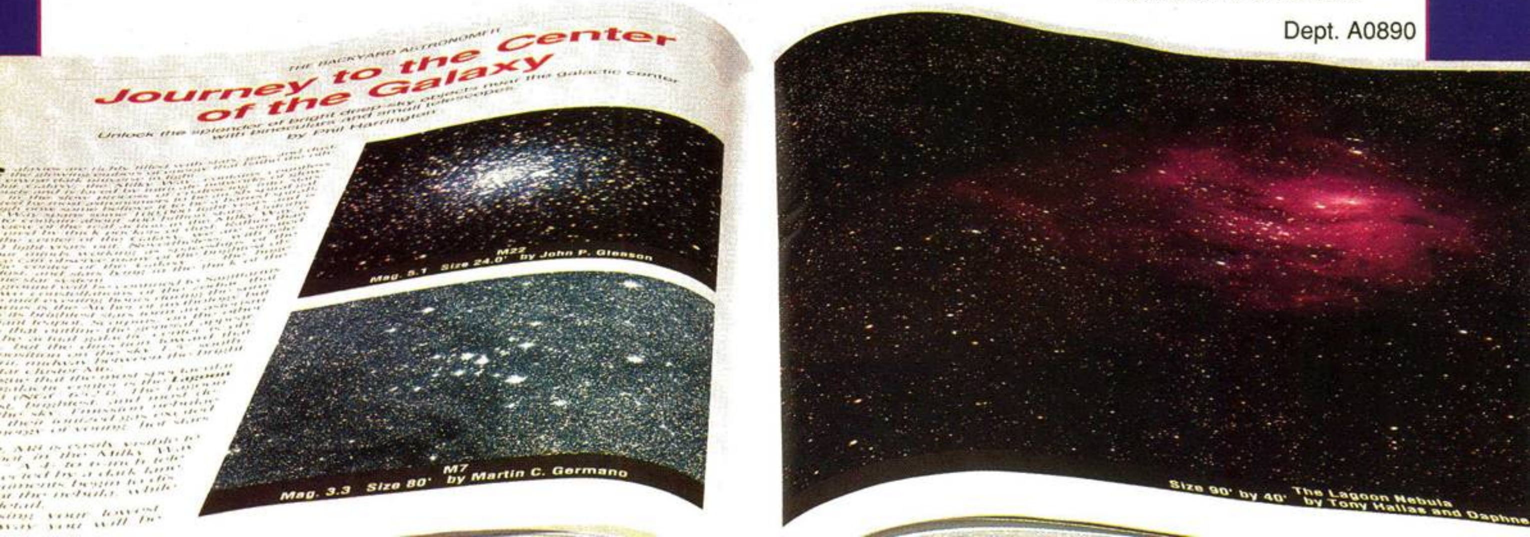
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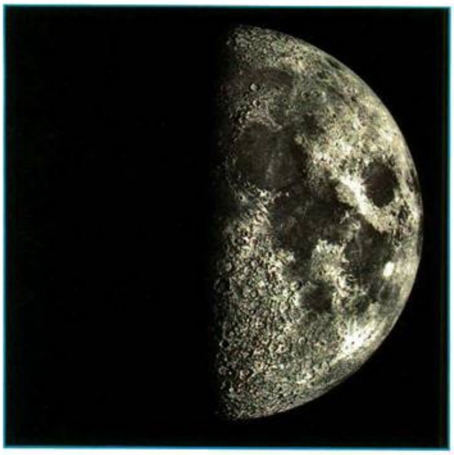
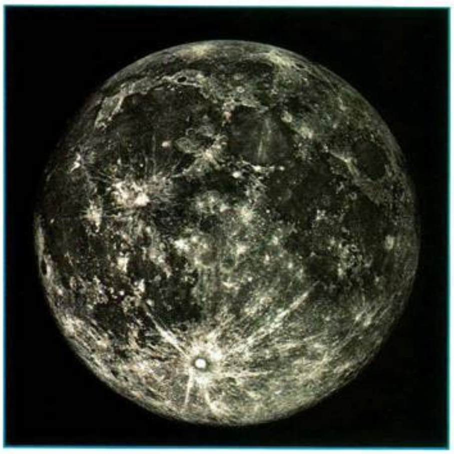
Not Just Another Pretty Phase

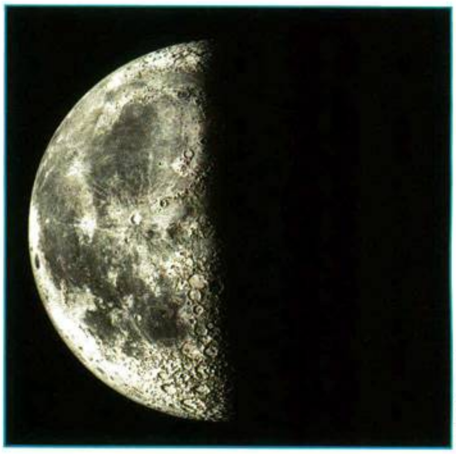
Knowing why the Moon shows different phases also helps you know where to look for it throughout the month.

by Mark J. Coco





THE CHANGING PHASES OF THE MOON occur because the Sun illuminates different parts of the Moon's visible hemisphere. First Quarter (far left) and Last Quarter (below) show half of the lit hemisphere and Full Moon (left) shows all of the lit hemisphere.



Lick Observatory

Watching the Moon over a month, you will notice its appearance change. Sometimes it's a thin sliver hanging in the western sky after sunset. Other times it's a lopsided football visible in broad daylight. At other times it's a giant white marble suspended against a black sky. These many faces of the Moon are its phases.

These phases result from the changing angle between the Moon, Earth, and the Sun. Even though half the Moon is always lit by the Sun, we see different parts of its illuminated hemisphere as our satellite moves in its orbit.

To picture how the Moon's motion creates the phases, imagine you're holding a ball in a room illuminated by a single light (see the image opposite). No matter where you hold the ball, it is always half lit by the lamp. But you see different amounts of the ball's lit surface depending on where the ball is. When the ball lies between you and the lamp, the illuminated side faces away and the ball appears dark. This corresponds to New Moon — the Moon lies between Earth and the Sun and its lit side faces away from us, making the Moon invisible in the sky.

Moving a quarter turn counterclockwise away from the lamp, you can now see half of the ball's lit face. Likewise, the face of the Moon in this position appears half lit. But this phase isn't called Half Moon. Rather, astronomers call it First Quarter, referring to the quarter of its orbit the Moon has traveled. For this and other visible lunar phases, you will see the Moon with the same phase everywhere on Earth, although the position of the Moon above or below the horizon will vary for different locations.

After another quarter turn, you face away from the lamp and the ball appears fully lit. In lunar phases, this corresponds to Full Moon. A third quarter turn brings the ball to a position where it again appears half lit, but now the illuminated half of the ball is opposite the half illuminated at First Quarter. For the Moon, this is Last Quarter.

Because these phases correspond with certain points in the Moon's orbit, the Moon will appear in predictable parts of the sky at different phases. For example, at New Moon the Moon lies in the same direction as the Sun. Even though you see — or don't see — the dark side of the Moon, it is there near the Sun and rises and sets with the Sun.

As the Moon moves in its orbit away from the Sun, the amount of illuminated surface you see increases. Because the Moon is moving east from the Sun, the first time you see the Moon's face after New Moon is in the west after sunset. The Moon appears as a thin crescent or, more properly, a waxing crescent Moon, with *waxing* coming from an old English word that means "to increase." Waxing phases include all those from New Moon to Full Moon. The waxing crescent phase encompasses the crescents from the thin crescent seen a night or two after New Moon to the fat crescent visible five or six days after New Moon. During this time, Northern Hemisphere observers see the right side of the Moon. As the Moon waxes, it becomes the second brightest object in the sky — second only to the Sun — making it an easy object to spot even during the daytime.

Finding the crescent soon after New phase was important to many cultures that used the Moon to set religious holidays, and still is for many cultures that continue to use it. But it is a challenge to see the crescent as soon as possible after New Moon. The current record holder saw the Moon when it was a little under 12 hours old.

About seven days after New, the Moon is at First Quarter and lies 90° from the Sun. That means it rises at noon and lies on the meridian (the line that cuts north and south through the sky) when the Sun sets, appearing at its highest point above the horizon. As evening progresses, the Moon moves toward the western horizon, finally setting around local midnight. This motion of the Moon toward the western horizon is caused by Earth's rotation. Because of its orbit around Earth, the Moon itself slowly moves west to east against the background stars. This motion is apparent if you plot the position of the Moon on a star chart one night and then check it the next night.

The next phase is waxing gibbous and occurs when the Moon is between First Quarter and Full. *Gibbous* comes from a Latin word that means "hump" and reflects the shape of the lit surface protruding beyond the quarter phase. The illuminated surface during the waxing gibbous phase continues to grow, lighting the majority of the Moon that faces Earth. The waxing gibbous Moon first appears in the eastern sky in the afternoon and is easily seen around sunset. As the night progresses, the Moon shifts to the western sky where it sets before sunrise.

When the Moon lies directly opposite the Sun, you see its face fully illuminated. The Full Moon rises in the east as the Sun sets, and sets in the west as the Sun rises, making it visible all night. The Moon's bright light is almost like a giant floodlight: See if you can spot a shadow cast by the Full Moon.

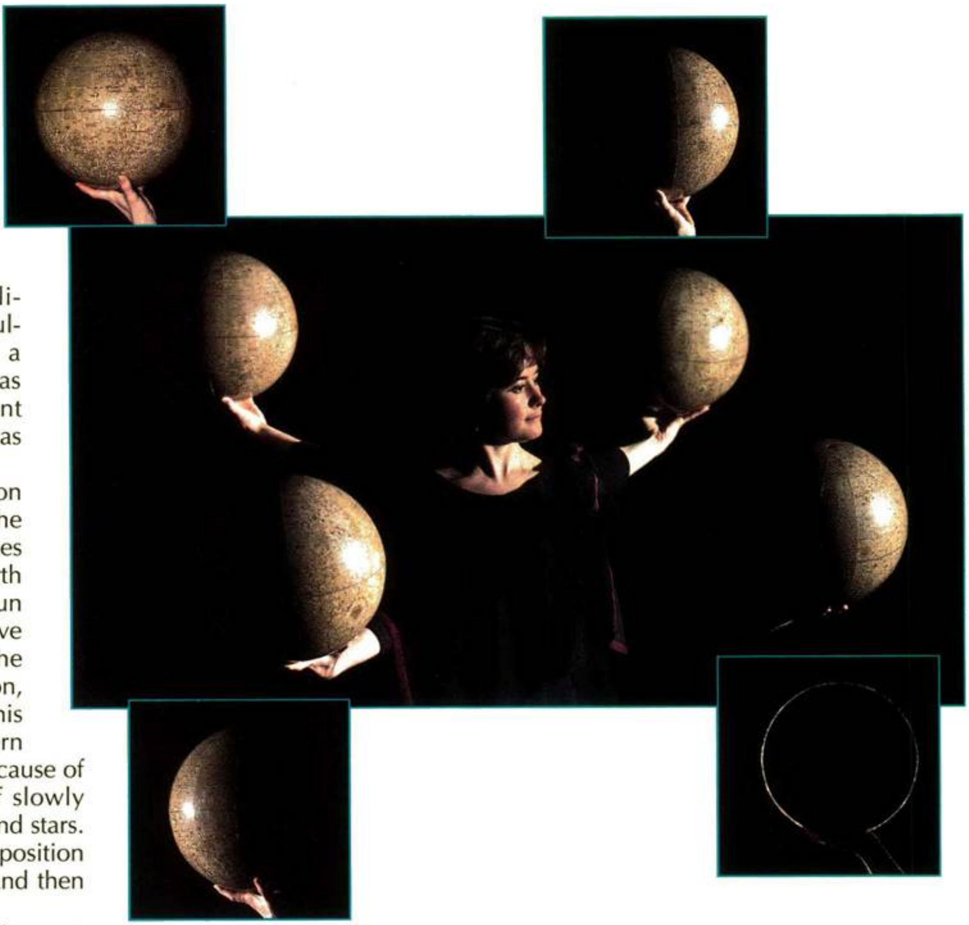
From the Full Moon on, the lunar phases repeat but in reverse order. Instead of waxing, they are now *waning* phases, from an Old English word which means "wanting" or "deficient." Starting with waning gibbous, the Moon has the familiar gibbous shape, except now the amount of illumination we see is decreasing. Lunar craters and mountains take on a new look through binoculars and small telescopes as shadows fall in the opposite direction for the waning Moon than they did for the waxing Moon. The gibbous Moon rises in the east after sunset and lies above the western horizon at sunrise.

At Last Quarter, the Sun illuminates the side of the lunar surface opposite from the one it illuminated during First Quarter. The Last Quarter Moon appears in the morning sky, rising around midnight, and lies on the meridian near sunrise.

The last leg of the lunar trip is the waning crescent, when the Moon is between Last Quarter and New. The amount of illumination we see continues to decrease as the Moon moves toward New. The waning crescent appears at its best in the morning sky before sunrise, but you can see wider crescents during the morning hours after sunrise.

After the waning crescent, the Moon returns to New, moving through the sky with the Sun. It takes 29.5 days to complete one cycle of phases from New Moon to New Moon. This period gave rise to the month in ancient calendars. ASTRONOMY's Sky Almanac lists the times of the four major phases — New, First Quarter, Full, and Last Quarter. Deep-sky observers keep track of the lunar phases because observing around New Moon is best. The bright light during other phases interferes with deep-sky viewing.

Watching the Moon go through a complete cycle of phases requires no special equipment, just a clear sky and the unaided eye — it's something you can do from your backyard. And the best part is that the Moon repeats its show every month. ☐



ASTRONOMY: Chris Becker and Thomas L. Hunt

YOU CAN SEE HOW PHASES OCCUR by holding a ball in a room with a single lamp turned on and its shade removed. As you turn, watch how the half-lit ball reveals different amounts of its illuminated surface (insets).

Mark J. Coco is an avid amateur living in the Los Angeles area who writes frequently for ASTRONOMY. His last article was "High-Impact Astrophotography" (April 1994).

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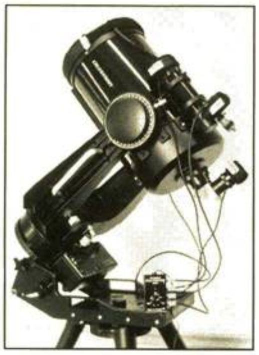

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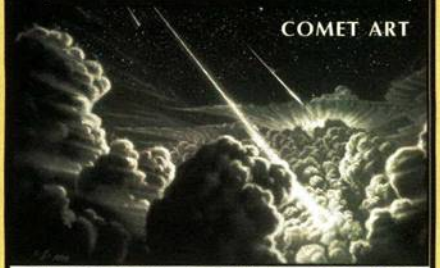

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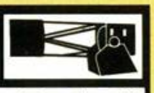

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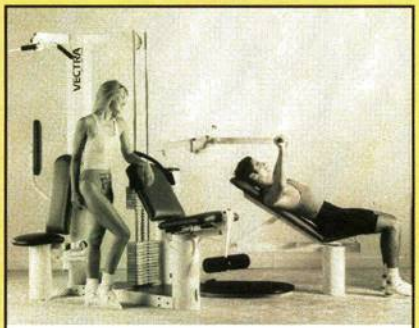

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6.6"-8.5"	117.00	87.00	152.00
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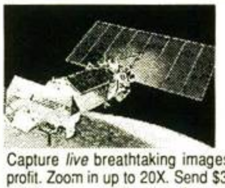

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Capturing Galaxies in Color

James Foster has a particular passion for photographing galaxies. Frequently he loads up equipment, readies his film, and drives from Hollywood up to Mount Pinos, California, for a long night of collecting photons. For several years Foster specialized in high-resolution black-and-white photography using the sharp Kodak Tech Pan film hypersensitized to increase its efficiency. Now Foster has taken the process a step further by shooting several Tech Pan exposures of the same object through different filters and combining the images in Adobe Photoshop to produce a final color frame.

"The tricolor approach using Tech Pan preserves the sharpness of black-and-white images and captures the beautiful colors visible in long-exposure color photos of faint objects," says Foster. "Although the process is rather painstaking, it creates bright, colorful images of low-contrast deep-sky objects like galaxies."

Foster uses his 11-inch SCT at f/6, an ST-4 autoguider, and a battery of filters. To create a recent shot of IC 342, a faint galaxy in Camelopardalis, Foster made four long exposures of the galaxy before combining them electronically. They lasted 210 minutes (#47A blue filter), 158 minutes (#25 red), 152 minutes (#23A light red), and 95 minutes (#11 yellow-green). After collecting the 10¼ hours of exposure time, Foster spent another 10 hours perfecting the image on his computer.

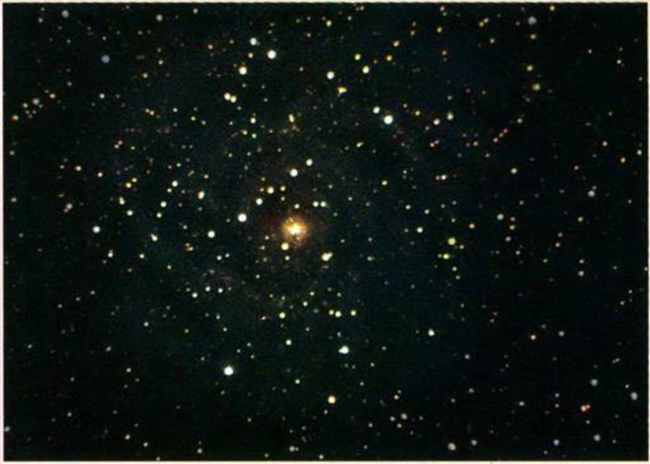
He varies the filter combinations experimentally from picture to picture. "For the IC 342 shot, I used the two red images to make the red features like H II regions appear less 'noisy' and included the yellow-green frame to give a slightly warm cast to the shot," says Foster. For a similar image of M106 in Canes Venatici, Foster used blue, yellow-green, and hydrogen-alpha filters. "And for the record," he says, "as the hydrogen-alpha exposure was being made, the Northridge earthquake of January 17, 1994, occurred. I was in the back of my truck, and my friend Marty Germano was making another photo nearby. As the shaking increased, my autoguider beeped as it lost its star, but after 15 seconds or so the major jolts stopped and the guider reacquired the star and resumed as if nothing had happened."

Geminids and Quadrantids. Many observations of autumn and winter meteors appeared in ASTRONOMY's offices. Most centered on December's Geminid shower. Jay Edwards, James Eggleston, and Jerry Babcock observed the event on December 13/14 from the Kopernik Space Education Center in Vestal, New York. Edwards writes, "We observed hundreds of meteors over a twelve-hour period. At 1:20 a.m. on the 14th we saw a sudden flash and looked around to see the end of a fireball trail between Ursa Major and Leo. It presented a fascinating sight with the train bisected by a dark gap. Our guess was that the meteor shone at magnitude –8 or –10."

Normand Matte of Boucherville, Quebec, watched the Geminids from a cabin about 150 miles north of Montreal. "My friend and I set up on a frozen lake and enjoyed watching the shower despite the cold temperature. We saw 30 meteors in an hour," says Matte.

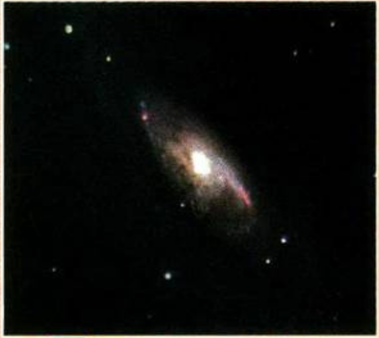
A group of Hungarian amateurs watched the Quadrantid shower on January 4, 1994, from the Matra Mountains northeast of Budapest. "Four observers each spotted between 10 and 20 Quadrantids per hour, with the radiant near the horizon," reports Istvan Tepliczky of the Hungarian Astronomical Association's meteor section.

ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187. Please label each photo with name, address, and social security number. You may send written reports via Internet to: 72000.2704@CompuServe.com



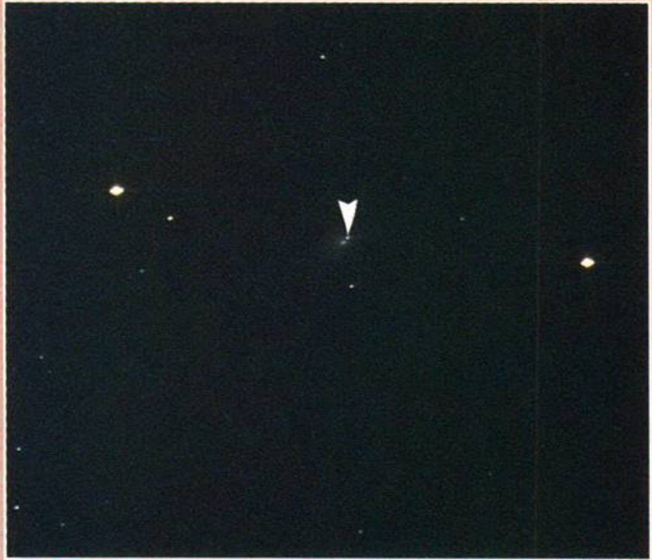
IC 342 in Camelopardalis

by James R. Foster
(11-inch SCT at f/6, hypersensitized Tech Pan film, composite of 210-minute blue, 158-minute red, 152-minute light red, and 95-minute yellow-green exposures)



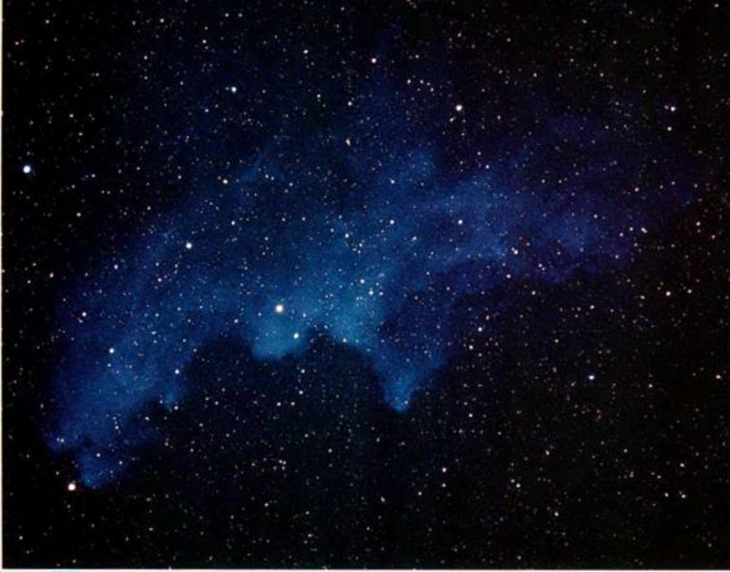
M106 in Canes Venatici

by James R. Foster
(11-inch SCT at f/6, hypersensitized Tech Pan film, composite of 195-minute blue, 180-minute hydrogen-alpha, and 95-minute yellow-green exposures)



Supernova 1994D in NGC 4526

by Ronald E. Royer
(12.5-inch f/7 reflector, ISO 400 film, 5-minute exposure on March 14, 1994)

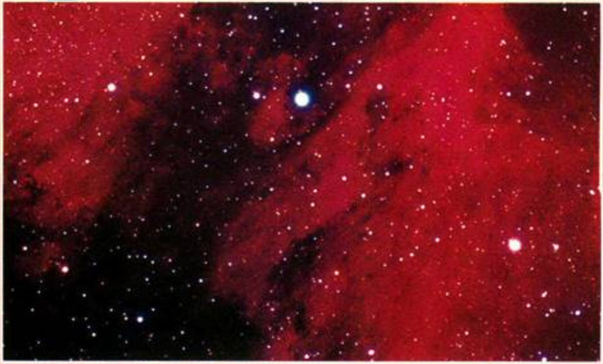


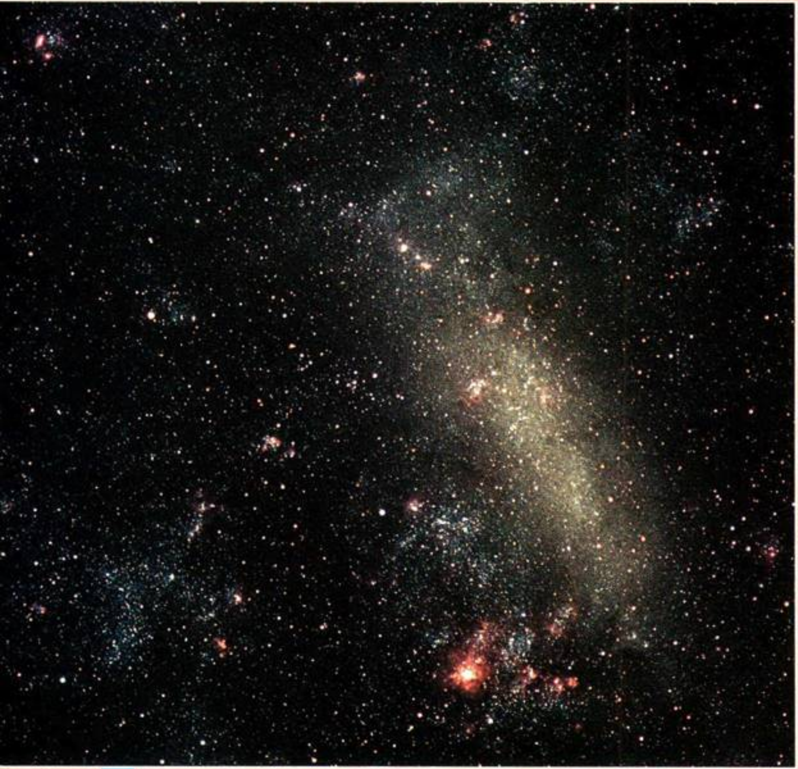
The Witch Head Nebula (IC 2118)

by George Greaney
(6-inch f/7 refractor, composite of two 50-minute exposures on Fuji Super HG 400 film)

The Pelican Nebula (IC 5067-70)

by Jason Ware
(6-inch refractor, Fuji Super HG 400 film)





The Large Magellanic Cloud

by Luke Dodd
(300mm lens at f/4, hypersensitized Fuji Super HG 400 film, 30-minute exposure)

STARS SHINE OVER LAS CAMPANAS

In November 1993 Arizona backyard skygazer Tom Polakis traveled to Las Campanas Observatory in Chile for several days of high-powered Southern Hemisphere observing. While at Las Campanas, Polakis photographed star trails and the faint glow of the Large Magellanic Cloud over the observatory's 40-inch and 24-inch domes. The trailed parking lights are from a sandwich delivery vehicle. His image wins this month's $100 "Best Astrophoto" award.

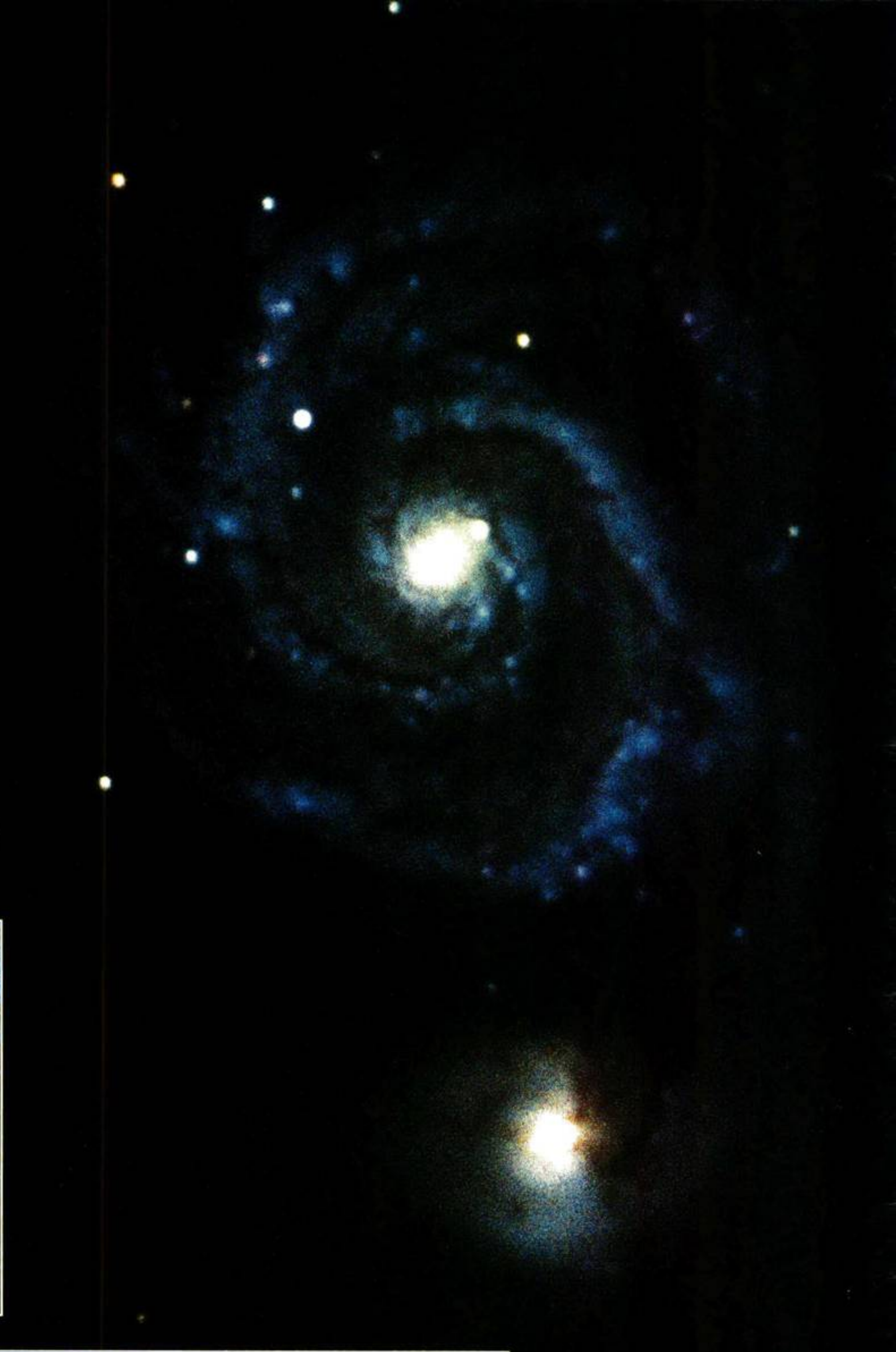
Southern Star Trails and the Large Magellanic Cloud

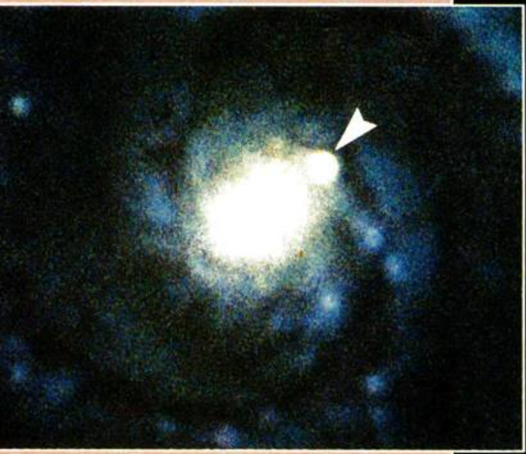
by Tom Polakis
(28mm lens at f/2.8, ScotchChrome 400 film pushed to ISO 800, 60-minute exposure)

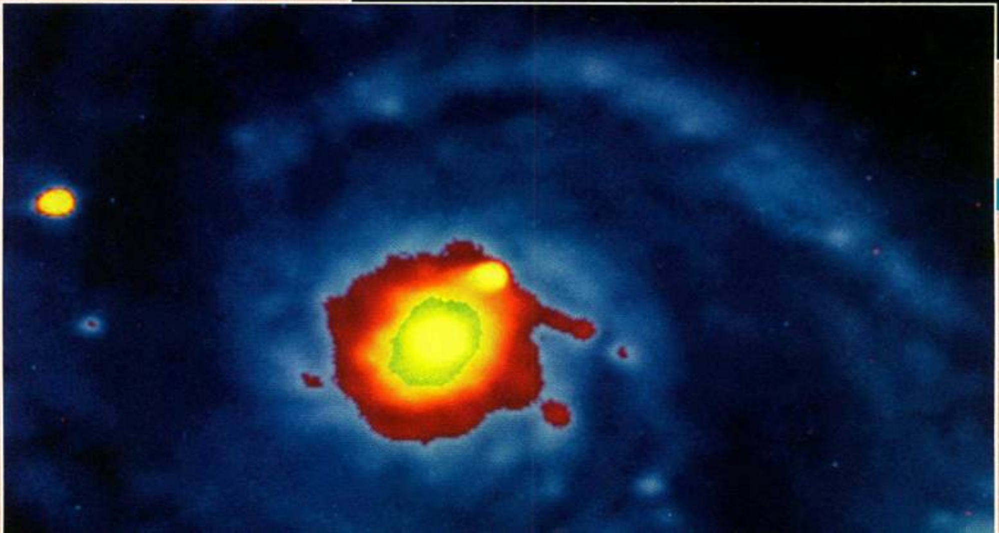
SUPERNOVA IN THE WHIRLPOOL!

Early in April a supernova exploded in M51, the bright Whirlpool Galaxy in Canes Venatici. Among the first photos we received of it are those by George Greaney and Dan Easton of Las Vegas, Nevada (right), and Wayne Johnson and Douglas Millar of the Orange County [California] Astronomers.

by George Greaney and Dan Easton (April 16; 14-inch SCT at f/11 on hypered Fuji SHG400; two 50-minute exposures sandwiched)







by Wayne Johnson and Douglas Millar (April 2; 22-inch Cassegrain at f/8, Starlight Xpress CCD camera, 120-second exposure; false color added)

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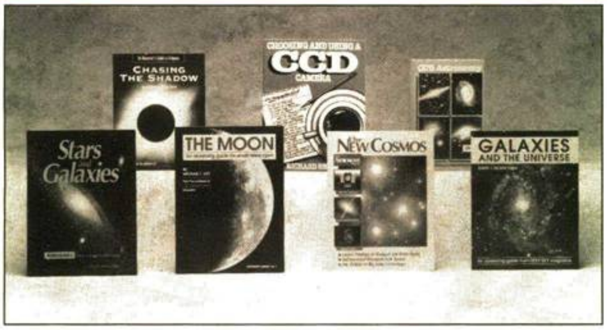

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June 16
Monthly Observatory Night, Phillips Auditorium, Cambridge, Massachusetts. Contact Harvard-Smithsonian Center for Astrophysics, Public Affairs Office, 60 Garden Street, Cambridge, MA 02138, (617) 495- 7461.

June 24
Dark Stars: New Light on Black Holes, Toronto, Ontario. Contact the McLaughlin Planetarium, 100 Queen's Park, Toronto, Ontario, M5S 2C6 Canada, (416) 586-5736.

June 25
Ninth Annual Sedona-Verde Valley Astronomy Festival, Red Rock State Park, Arizona. Sponsored by Verde Valley Astro-Center. Contact the Verde Valley Astro-Center, 1101 Zalesky Road, Cottonwood, AZ 86326, (602) 634-7332.

June 25-26
National Workshop on Teaching Astronomy in Grades 3-12, Northern Arizona University, Flagstaff, Arizona. Sponsored by the Astronomical Society of the Pacific. Contact Teachers' Workshop, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

June 25-26
Universe 94, Northern Arizona University, Flagstaff, Arizona. Sponsored by the Astronomical Society of the Pacific and ASTRONOMY. Contact the Astronomical Society of the Pacific, Meeting Information, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100.

June 28-July 5
Astronomy Camp for Teens (Advanced), University of Arizona, Tucson, Arizona. Sponsored by the University of Arizona Alumni Association. Contact Lisa Roubal, 1111 N. Cherry, Tucson, AZ 85721, (602) 621-5233, or (800) 232-8278 outside Arizona.

July 1-4
Star Stare '94, Pike's National Forest, Colorado. Sponsored by the Colorado Springs Astronomical Society. Contact Mike Frazier, CSAS Star Stare, P.O. Box 62022, Colorado Springs, CO 80962, (719) 591-9349.

July 8-9
Gateway to the Universe '94, Munro Park, Powassan, Ontario. Sponsored by The North Bay Astronomy Club. Contact Merlin Clayton, 50 Van Horne Circle, North Bay, Ontario, Canada P1A 3L3, (705) 472-1182.

July 8-10
Wisconsin Observer's Weekend (W.O.W.), Hartman's Creek State Park, Waupaca, Wisconsin. Sponsored by NEWSTAR. Contact Don Wyman, 1065 Laager Lane, Oshkosh, WI 54901, (414) 233-3083.

July 16
Comet Crash Watch, Farpoint Observatory, Eskridge, Kansas. Sponsored by the Northeast Kansas Amateur Astronomers' League, Inc. Contact Brenda Culbertson, NEKAAL, P.O. Box 951, Topeka, KS 66601, (913) 589-2405.

July 28-30
ALCON '94, Avila College, Kansas City, Missouri. Sponsored by the Astronomical Society of Kansas City. Contact Carroll Iborg, 7241 Jarboe, Kansas City, MO 64114.

July 30-August 7
3rd Annual Summer Star Party & Family Camping Vacation, Shady Pines Camp Ground, Savoy, Massachusetts. Sponsored by the Rockland Astronomy Club. Contact Don Urban, 73 Haring Street, Closter, NJ 07624, (201) 768-6575.

August 5-7
Annual Summer Star Party, Foxpark, Wyoming. Sponsored by the Cheyenne Astronomy Society. Contact Marty Curran, 6614 N. College, #G, Cheyenne, WY 82009, (307) 635-5944.

August 5-7
Starfest '94, River Place Campground, Mount Forest, Ontario. Sponsored by the North York Astronomical Association. Contact Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5. □

Clubs, please submit announcements at least four months in advance to Tracy Staedter, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612. Readers, when you write to organizations listed in "Meetings and Events," include a large, self-addressed stamped envelope with your request for information.

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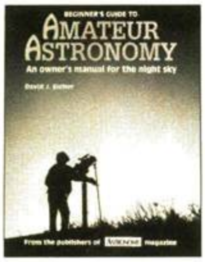

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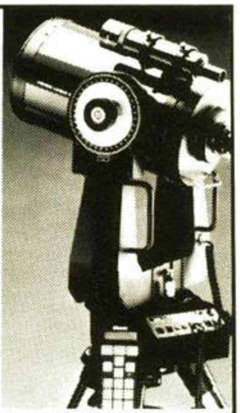

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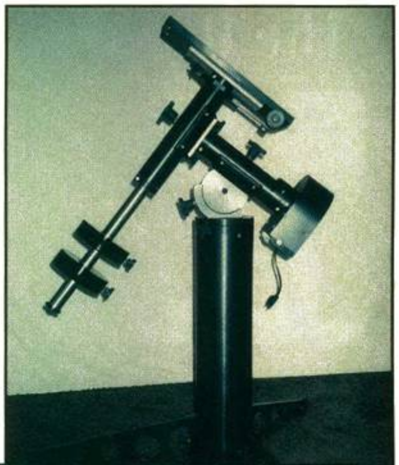

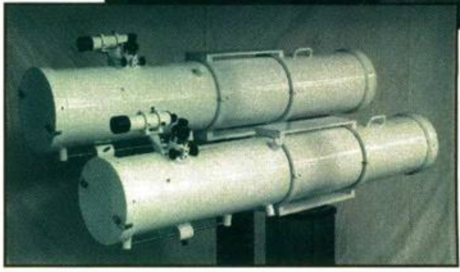

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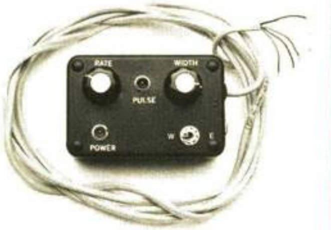
Parallax Instruments, Suite 708, Box 192, 8318 Pineville, Matthews Road, Charlotte, NC 28226, (704) 542-4817, fax: (704) 541-8985. 6-inch tube assembly: $795, 8-inch: $1,695 (pictured, back), 10-inch: $2,095 (pictured, foreground), 12.5-inch: $2,795, 14.5-inch: $3,495, 16-inch: $ 4,295. German equatorial mounts: Model 100: $1,295, Model 150: $1,895 (pictured), Model 200: $2,995, Model 250: $3,795.



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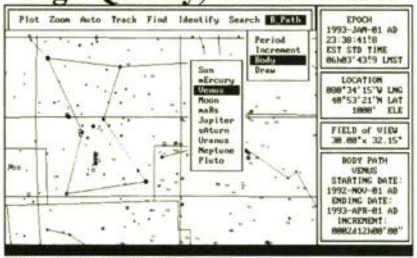

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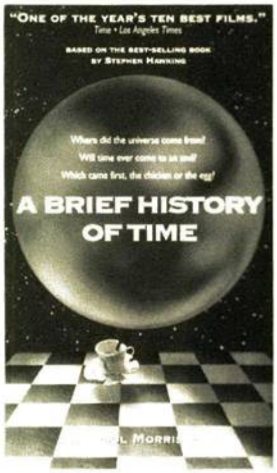
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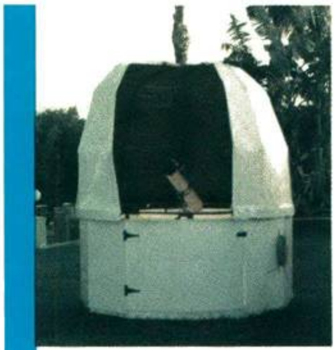

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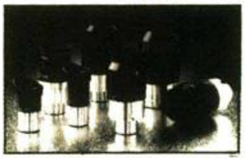

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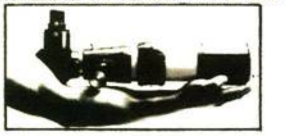

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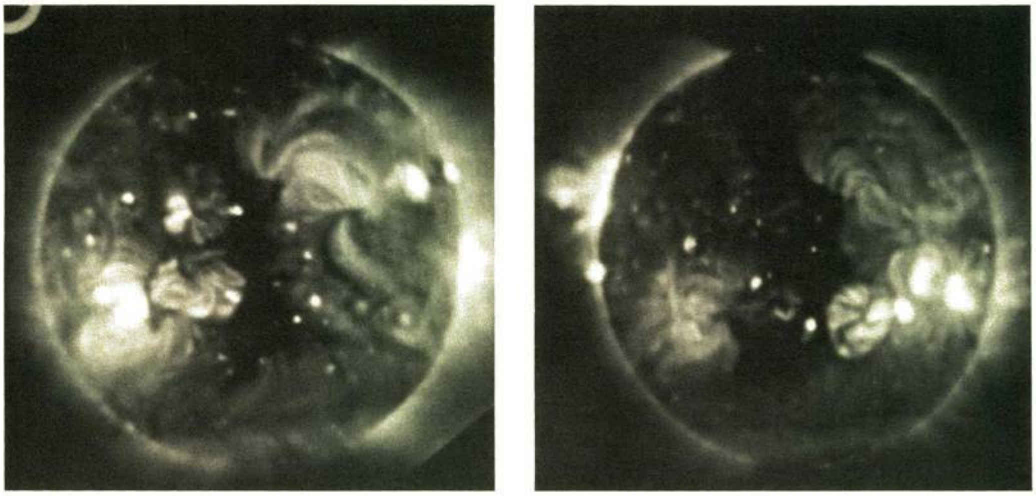
AstroBytes

New Software Roundup

Skylab X-ray Image Viewer (1.5)
David Batchelor, Code 632, Space Physics Data Facility, NASA Goddard Space Flight Center, Greenbelt, MD 20771. Minimum requirements: IBM PC-compatible computer, VGA display, and 3.7 MB of hard disk space.

A few new features appear in this version of the Skylab image display program (see AstroBytes, February 1993). One is a sequence of images that show the Sun's rotation and the evolution of magnetic features in the Sun's atmosphere. A second lets users with a Super VGA display (1024x768 mode) explore a high-resolution copy of an image. And a before-and-after comparison demonstrates how processing improves the raw Skylab images.



David Batchelor/NASA

Another comparison shows how much the Sun can change in one rotation period. The images shown above are the ones used in this comparison. Coincidentally, the printed images also form a stereo pair. If you relax your eyes, the images will merge to form a 3-D picture of the Sun.

MegaStar (1.87) CD-ROM
E.L.B. Software, 8910 Willow Meadow, Houston, TX 77031, (713) 541-9723. Minimum requirements: 80286-based computer, DOS 3.2, 500KB of free memory, VGA display, 1 MB of hard disk space, and a CD-ROM drive. Price: $139.

E.L.B. Software has added several features to MegaStar since we reviewed it in October 1993 (version 1.51). The biggest change is that the program, which includes the Hubble Guide Star Catalog, now comes on a CD-ROM instead of dozens of diskettes, making the program easier to load and use. You no longer need 8 to 54 MB of hard disk space to store this program. The display routine now uses a conic projection to more accurately portray fields between 60° and 90° in declination. The earlier limitation preventing viewing of fields higher than 80° no longer exists. But you still can't display the poles because the program doesn't contain a polar projection routine.

Star charts now print at higher resolution on laser printers (150 dots per inch instead of 75 dpi) and 24-pin dot-matrix printers (180 dpi). Stellar data now include the Smithsonian Astrophysical Observatory catalog information. This means that you can label stars with their Bayer (Greek letter), Flamsteed (number), or SAO catalog number designations. Data boxes for stars in the Guide Star Catalog now list magnitudes to the nearest 0.1, instead of 0.5, magnitude. Although MegaStar doesn't yet display constellation boundaries (a future version will include this feature), the data box indicates which constellation an object lies in. For CCD camera users, a "CCD framer" displays a box showing your camera's field of view to check the framing of sky images.

Earth Centered Universe (1.5)
Nova Astronomics, P.O. Box 31013, Halifax, NS B3K 5T9, Canada, (902) 443-5489. Minimum requirements: 80386-based computer, DOS 3.X, Windows 3.X, 700 KB of free memory within Windows (1 MB for the enhanced version), 2.3 MB of hard disk space (5.5 MB for the enhanced version), EGA display, and a mouse. Recommended: VGA display and a math coprocessor. Price: $35 ($40 Canadian); $55 ($63 Canadian) for enhanced version with SAO star catalog. A French-language version is also available.

Earth Centered Universe is a planetarium-type program that offers the convenience of pull-down menus and mouse clicks because it uses the Windows graphical user interface. It displays 9,100 stars down to magnitude 6.5 (about 250,000 stars down to magnitude 9.5 from the Smithsonian Astrophysical Observatory star catalog with the enhanced version). The database also includes more than 10,000 deep-sky objects. You can follow the motions of the Sun, Moon, planets, and up to 50 comets and asteroids from 4713 B.C. to A.D. 10,000. Clicking on an object opens an information box that lists the object's name or designation, position, brightness, and rise and set times. For solar system objects, the box also includes distance, size, and phase. A red-light screen mode protects your night vision if you use the program at the telescope. You can set circles to different sizes to show the field of view of a finderscope or telescope. You can customize a star chart and then print it using any Windows-compatible printer. And if you have a Meade LX-200 or JMI's SGT-MAX, you can use Earth Centered Universe to help run your telescope.

Satellite Tracker (1.33)
Intellimation, P.O. Box 1922, Santa Barbara, CA 93116-1922, (805) 968-2291. Minimum requirements: Macintosh computer, System 6.0.5, 1 MB of free memory, and 400 KB of hard disk space. Price: $39.

Follow satellites as they orbit Earth with Satellite Tracker. You can view the tracks of several through the sky or trace their motions over Earth's surface. The program includes the orbital elements needed to calculate the paths of over 150 satellites or you can add "two-line" elements available from many electronic bulletin boards. To help indicate a satellite's visibility, a square indicating the satellite's position changes from an open symbol to a filled-in one to show it has entered Earth's shadow and become invisible. The manual describes astronomical coordinate systems, orbital motion theory, and downloading orbital elements from bulletin boards. It also includes sample exercises for home study or use in the classroom.

Voice Controlled Telescopes

Analytical Scientific, 11049 Bandera Road, San Antonio, TX 78250, (800) 701-7827. Minimum requirements: 80386-based computer, DOS 5.0, Windows 3.1, hard drive, and a 16-bit expansion slot. Price $595, plus $89 for SkyTalk and $99 for CCDTalk.

Tired of punching a keyboard in the dark? With Voice Control, you can tell your scope on a Meade LX-200, 600, or 700 series mounts where to point using TheSky and SkyTalk software with simple voice commands ("Find M81"). If you have a CCD camera, you can also control it with your voice using SkyPro and CCDTalk software ("Take CCD exposure, 2 minutes"). Voice Control also works with Windows' Program Manager, WordPerfect, and Microsoft's Excel, Word, and Write.

Space and Astronomy CD-ROM

Walnut Creek CDROM, 1547 Palos Verdes Mall, Suite 260, Walnut Creek, CA 94596, (800) 786-9907. Minimum requirements: Macintosh or IBM PC-compatible computer with a CD-ROM drive. Price: $39.95.

This CD-ROM contains more than 12,000 files and 565 MB of information. It's perfect for exploring the best material found on electronic bulletin boards. Or you or your club can start a bulletin board using the CD-ROM and the included index files for common BBS software. The disk contains 1,080 images of Earth, the planets, and select deep-sky objects. Many of the images are in the GIF format and the disk includes GIF viewer programs to facilitate display of the images. The Space and Astronomy CD-ROM also has popular shareware programs (such as SkyGlobe, NGP, IMDISP, SkyMap, and SatView) and 5,000 text files (for example, asteroid information, NASA press releases, and Usenet sci.space messages).

The Whole Internet User's Guide and Catalog

Ed Krol, (O'Reilly and Associates, 1994), ISBN 1-56592-063-5, 543 pages, acid-free paper, $24.95.

Those of you wanting to learn how to surf on the information superhighway might want to check out this book on the Internet. Krol in the second edition of this book explains the workings of the Internet collection of networks, protocols for information transfer, network ethics, and user names. He also describes Internet tools such as *telnet* for remote computer login, *ftp* for file transfer, and *Archie* for finding files. ☐

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Aperture	Mounted	Aperture	Unmounted
2.4"	$49.00	2.4"	$39.00
3.1"	52.00	3.1"	42.00
3.5" to 4"	59.00	3.5 to 4"	49.00
4-1/4" to 5"	74.00	4-1/4" to 5"	64.00
6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
11"	119.00	11"	109.00
12.5" to 13.1"	149.00	12.5" to 13.1"	129.00
14"	169.00	14"	149.00

40mm to 80mm Binoculars - Mounted .... $92.00 pr.

GLASS (Full Aperture) Type 2

Same as type 1, except stainless steel is combined in the coating to provide an even more durable surface that highly resists wear due to excessive handling and ultraviolet radiation. Solar image is also yellow-orange.

Aperture	Mounted	Aperture	Unmounted
2.4"	$62.00	2.4"	$52.00
3.1"	65.00	3.1"	55.00
3.5" to 4"	76.00	3.5 to 4"	66.00
4-1/4" to 5"	96.00	4-1/4" to 5"	86.00
6"	105.00	6"	95.00
8"	125.00	8"	109.00
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40mm to 80mm Binoculars - Mounted .... $115.00 pr.

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Coated to a neutral density of 4 for serious astrophotographers who desire the shortest possible shutter speeds with slow films. Solar image and optical quality same as type 1 & type 2. Type 3 filters are for photographic use only.

Aperture	Mounted	Aperture	Unmounted
2.4"	$79.00	2.4"	$65.00
3.1"	82.00	3.1"	69.00
3.5" to 4"	99.00	3.5 to 4"	79.00
4-1/4" to 5"	125.00	4-1/4" to 5"	110.00
6"	135.00	6"	115.00
8"	159.00	8"	139.00
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11"	199.00	11"	179.00
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Right Stuff to the Moon

A Man on the Moon

Andrew Chaikin, (Viking Press, 1994), ISBN 0-670-81446-6, 655 pages, softcover, $24.95.

More than a third of the people alive today were just kids when Apollo 11 made history in one bold stroke. All I recall from that July 1969 evening are fuzzy, wraithlike (they did look scary, didn't they?) humanoid-blobs bouncing across a lunar surface that looked just as confusing. Apollo 11 was a vast technical and engineering achievement, but what was it like for the two men who were there, let alone the ten who followed? *A Man on the Moon* bridges that gap between the technical and human, providing the rest of us with a lively story of Apollo as seen through the eyes of those who made those first tentative steps off the home planet.

NASA

The book opens with President Kennedy's 1962 speech at Rice University, which reiterated his goal to land a man on the Moon and then winds through the triumphs and tragedies of America's manned lunar effort, up to the bittersweet conclusion of Apollo 17 — Apollos 18, 19, and 20 were scrapped. (The Saturn Vs that were to have launched them are now outdoor exhibits at the Kennedy, Marshall, and Johnson Spaceflight Centers). An epilogue takes the reader through present day, telling what has happened to each of the Apollo players and how the lunar experience changed their lives, for better or worse.

Author Andrew Chaikin culled this Apollo history from interviews with astronauts, their families, and engineers, and through years of research in NASA archives. He even pored over Apollo cockpit voice recorder transcripts only recently released by the space agency. Armed with this first-hand information, Chaikin provides many fascinating recollections from those who blazed the trail to the Moon.

One story relates to the tragic Apollo 1 fire: Donald K. Slayton, Mercury astronaut and head of the astronaut office, came close to sitting in on the ill-fated January 1967 spacecraft training session that killed astronauts Edward White, Virgil Grissom, and Roger Chaffee. Over breakfast the morning of the accident, Grissom complained to Slayton that the command module was full of problems: "If you don't believe me," he said, "come see for yourself." Slayton seriously considered the offer but declined, feeling he would have a better perspective in the nearby blockhouse. Later that evening fire swept through the capsule, suffocating the three astronauts on board. To his dying day, Slayton felt that maybe, from a jumpseat in the capsule, he might have spotted the spark caused by faulty wiring and put out the fire before it spread. More likely, Slayton would have perished in the flames, which spread throughout the capsule's pure oxygen atmosphere in a matter of seconds.

Four years later Apollo 14's Alan Shepard, whom colleagues referred to as the "Icy Commander," stood on the rolling hills of Fra Mauro, completely overwhelmed by the majesty of the moment. For several seconds it was all he could do to take in the scene, as tears welled up in his eyes and rolled down his cheeks.

A Man on the Moon is replete with similar tales of dreams realized and opportunities missed, all told from the hearts and souls of those who shaped and carried Kennedy's bold challenge to fruition. On this the 25th anniversary of Apollo 11's landing, I can think of no other book that has thus far done the program so much justice. Presented in the narrative tradition established by Tom Wolfe's *The Right Stuff*, Chaikin's book is a must-read for all who witnessed (or were too young to witness) that most wondrous achievement of a quarter-century ago. — *John Shibley*

Other Books Noted

Black Holes and Baby Universes and Other Essays

Stephen Hawking, (Bantam Books, 1993), ISBN 0-553-09523-4, 182 pages, hardcover, $21.95.

Fourteen essays present autobiographical sketches of Stephen Hawkings and explications of his research into black holes and the origin and future of the universe. Because most of the essays come from talks given by Hawking, the tone is conversational, which makes it attractive to most people who take their science in modest doses. Within the essays he discusses his philosophical positions on and public attitudes toward science, as well as the predictability of events in the universe, the physics of black holes, and the possible future collapse of the universe.

Reaching for the Stars

Peter Bond, (Cassell, 1993), ISBN 0-304-34089-8, 128 pages, hardcover, $22.95.

Reaching for the Stars traces in laymen's terms the U. S. and Russian space programs from Yuri Gagarin's first flight through the days of the Mercury, Gemini, and Apollo programs to the present efforts to design a space station. Bond describes the technological achievements that made manned spaceflight possible and the courage of the 250 astronauts who made it happen. He concludes the book with a discussion of the future directions of international space programs, which include possible missions back to the Moon and those on to Mars.

Sky Surveys: Protostars to Protogalaxies

B. T. Soifer, editor, (Astronomical Society of the Pacific, 1993), ISBN 0-937707-62-7, 323 pages, hardcover, $44.50.

The sky survey is a time-honored approach to learning about a diverse set of objects lurking in the cosmos. Using this method, astronomers build new instruments that can see with greater clarity to fainter limits or survey an unexplored region of the spectrum. Then they open the shutter and look at the entire sky, if possible, to see what can be discovered. Invariably something new pops out of the survey and fuels research. This book contains technical papers from a meeting held at Caltech in September 1992 and summarizes three dozen current and future surveys of our Galaxy, active galactic nuclei, and distant galaxies from space and ground-based

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observatories. Amateur astronomers with a solid background in college physics would find *Sky Surveys* an interesting read.

A Handbook to the Universe
Richard Paul, (Chicago Review Press, 1993), ISBN 1-55652-172-3, 285 pages, softcover, $14.95.

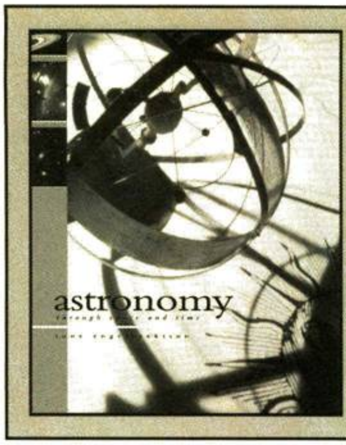
Richard Paul gathers useful information about time, matter, energy, light, sound, motion, electricity, relativity, the solar system, planetary orbits, nuclear reactions, and atomic physics into one volume. The thread that holds this all together is an exploration of how nature — and science — work. Paul succeeds in converting what would normally be dull textbook material into a practical and readable guide for persons interested in increasing their knowledge of the physical sciences.

Planets Around Pulsars
J. A. Phillips, S. E. Thorsett, and S. R. Kulkarni, editors, (Astronomical Society of the Pacific, 1993), ISBN 0-937707-55-4, 391 pages, hardcover, $44.50.

Astronomers discovered the first planets beyond our solar system orbiting a pulsar. These second-generation planets formed when the material ejected by the exploding star that created the pulsar coalesced. At a meeting in May 1992 held at Caltech, four dozen researchers gathered to describe their efforts to understand this class of planets and to discover planets around other stars. This volume summarizes the talks on pulsars, pulsar planets, orbits of planets around pulsars, planetary disks, and the formation and evolution of pulsars.

U. S. Space Gear: Outfitting the Astronaut
Lillian D. Kozloski, (Smithsonian Institution Press, 1994), ISBN 0-87474-459-8, 256 pages, hardcover, $39.95.

As humans flew higher and faster, the need for protective clothing became more acute. Using the Smithsonian Institution's National Air and Space Museum archives, Lillian Kozloski has put together a pictorial history of American spacesuit evolution, from the early days of high-altitude flight through the era of the space shuttle. Along the way she shares some interesting facts. For instance, elements found in today's suits can be traced directly back to inner tube designs for automobile tires, medieval armor and, believe it or not, an early researcher's study of tomato worms in his wife's garden. Space buffs will find this book both entertaining and informative. □



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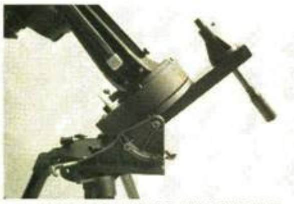

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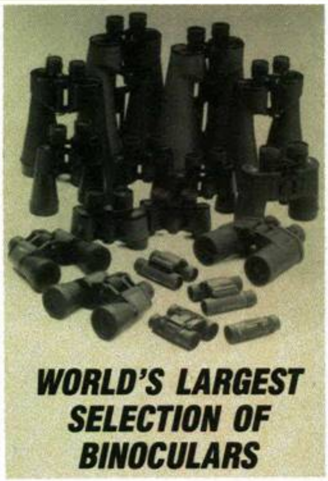

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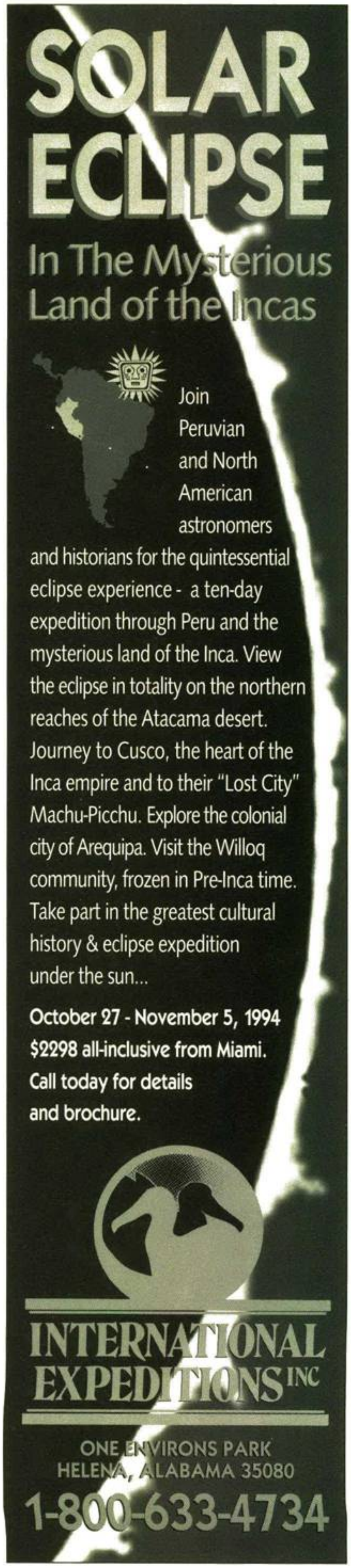
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Apollo's Gift: The Moon (page 40)

Lunar Sourcebook by Grant Heiken, David Vaniman, and Bevan French (Cambridge University Press, 1991). A detailed summary of lunar knowledge for professional scientists; contains summary chapters accessible to lay readers.

The Geologic History of the Moon by Don E. Wilhelms, (U.S. Geological Survey Professional Paper 1348, 1987). Excellent survey of lunar geological history; profusely illustrated; assumes familiarity with geology terms yet quite readable.

The Moon: An Observing Guide for Backyard Telescopes by Michael Kitt, (Kalmbach, 1992). Provides a friendly guided tour of the lunar surface and outlines its geological history.

Atlas of the Moon by Antonín Rükl, (Kalmbach, 1992). A beautiful and detailed lunar atlas by a master cartographer; essential for Moon observers.

Test Your Scope's Optics (page 40)

Telescope Optics by Harrie Rutten and Martin van Venrooij, (Willmann-Bell, 1988). Includes information about optical aberrations.

Bring on the Digital Darkroom Revolution! (page 62)

Multimedia and Kodak Photo CDs with CD-ROM by Heinz Von Bulow, (Abacus Books, 1994). Provides the latest word on using Photo CD technology with a home computer.

For a complete bibliography on Photo CD, call Kodak at (800) 235-6325.

Oh Say Can You See? (page 70)

A Handbook of Quasistellar and BL Lacertae Objects, by Eric R. Craine (Pachart, 1977). A superb guide that includes basic data, observational histories, and finder charts adapted from the Palomar Sky Survey for dozens of quasars brighter than 17th magnitude.

Uranometria 2000.0 by Wil Tirion, Barry Rappaport, and George Lovi, (Two vols., Willmann-Bell, 1988-1989). A detailed star atlas for the northern and southern skies that includes the positions of hundreds of quasars.

Not Just Another Pretty Phase (page 76)

The Observer's Handbook 1994, (The Royal Astronomical Society of Canada, 1993). Contains rise and set times for the Moon.

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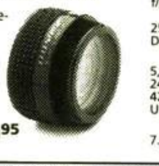

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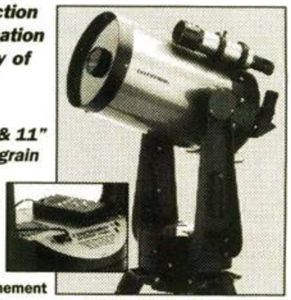

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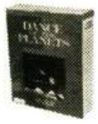

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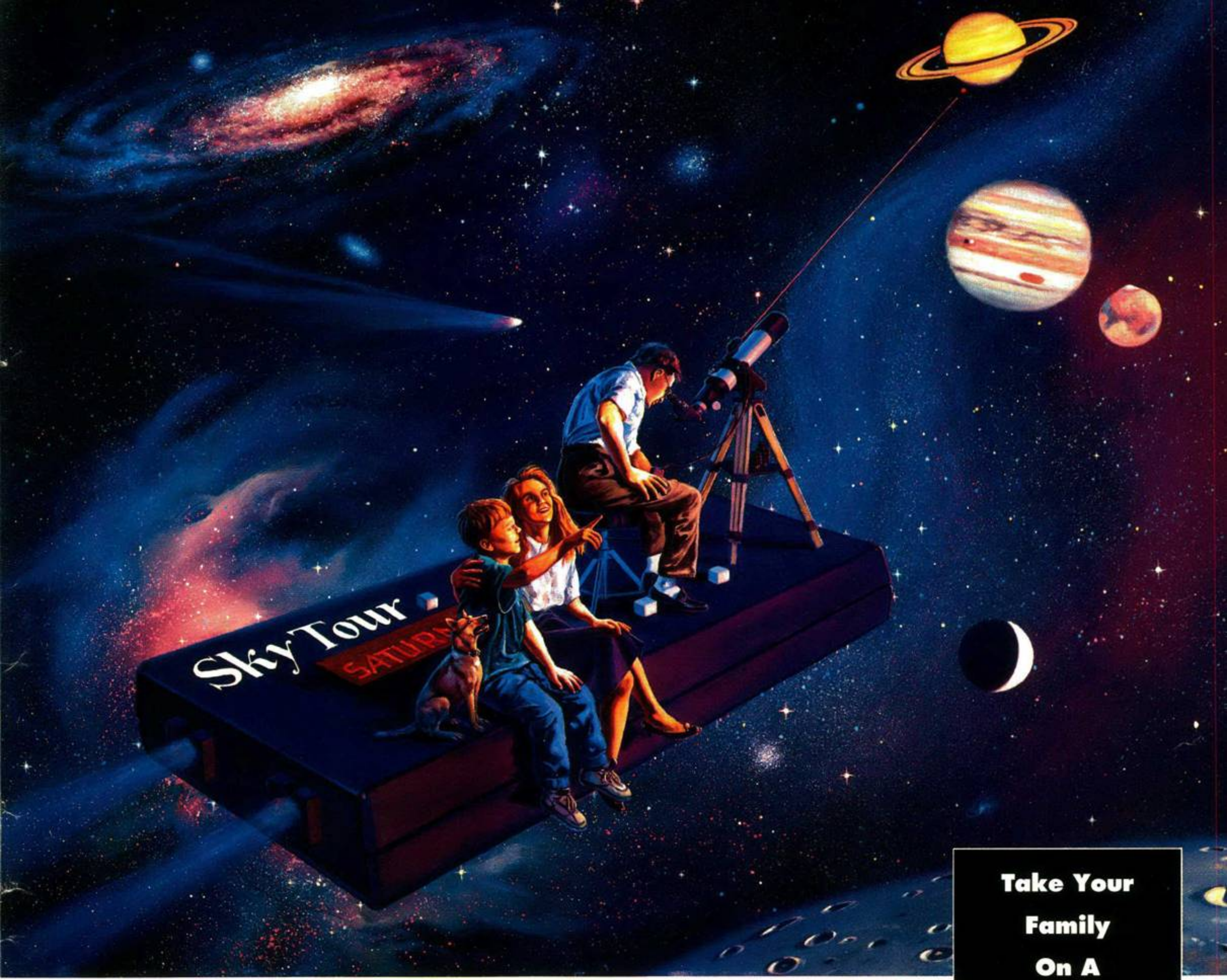

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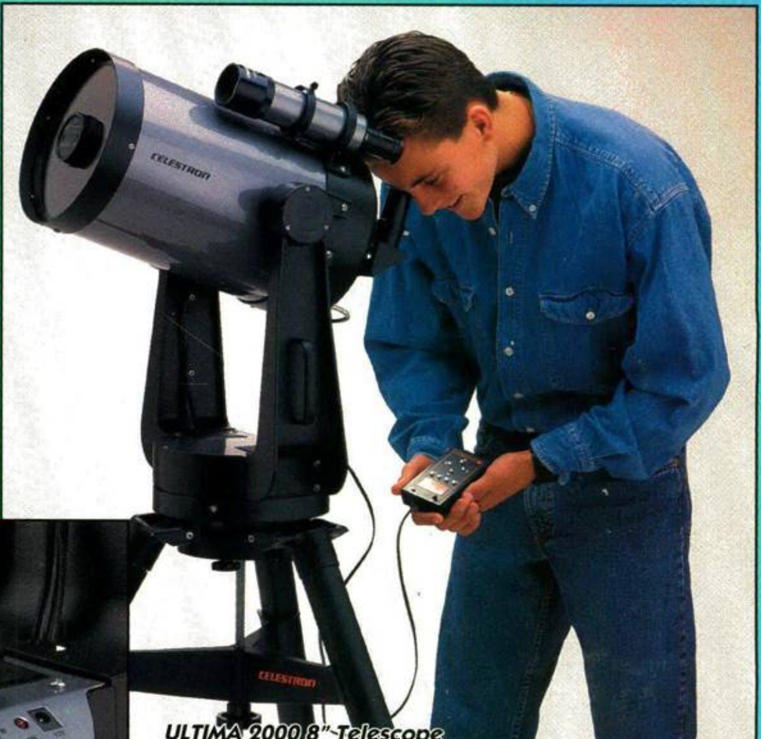

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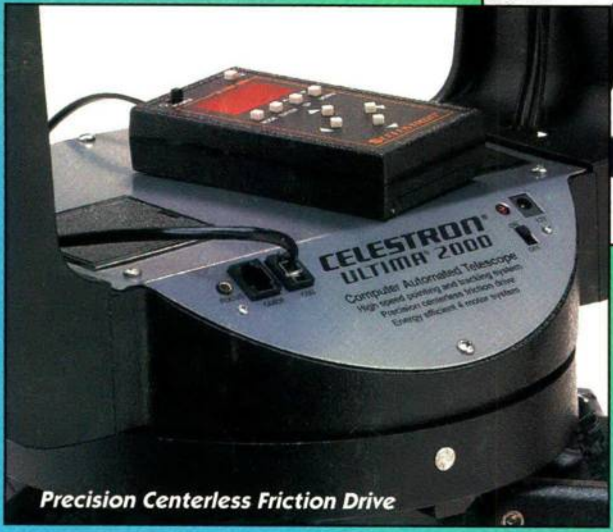

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